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Aeronautical Engineering REVIEW

June, 1955

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Aeronautical Engineering Review

Vol. 14—No. 6 June, 1955

CONTENTS

Bases Unlimited.....*Ernest G. Stout* 42

The Procurability Program of the Air Force.....*Otto H. Malz* 56

The Control of Turbojet Engines.....*Donald F. Winters* 62

Recent NACA Investigations of Noise-Reduction Devices for Full-Scale Engines.....*Edmund E. Callaghan, Newell D. Sanders, and Warren J. North* 66

Design Considerations for Cargo Aircraft.....*Winfield H. Arata, Jr.* 72

Take-Off Ground Run of an Airplane with Forced Circulation System of Boundary-Layer Control.....*A. N. Petroff and R. K. Wattson, Jr.* 79

IAS News Notes..... 33
IAS News..... 35
Editorial..... 40
Special IAS Publications..... 82
Aeronautical Reviews..... 123
Books..... 155
Personnel Opportunities..... 159
Index to Advertisers..... 160
New Products and Product Literature..... 163

Cover—The latest in sub-hunting equipment is displayed by this Grumman S2F in the first Navy-approved photo showing the radome and magnetic air-borne detection boom in extended positions. The spun-glass radar dome is telescoped down from within the fuselage when the S2F is searching for submarines, while the boom (commonly called the MAD-boom) is extended from the tail cone. The radar is used to detect and track subs on the surface; the magnetic air-borne detector is used to "home" on submerged submarines.

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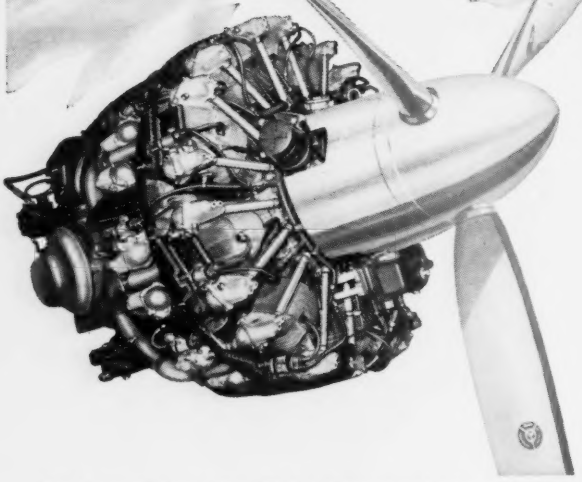

1955

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I.A.S. News Notes

June 1955

BANE AND CHANUTE AWARD WINNERS ANNOUNCED

Gottfried Guderley, a Civilian Scientist with the System Dynamics Research Branch, Aeronautical Research Laboratory, Wright Air Development Center, USAF, has been chosen to receive The Thurman H. Bane Award "for his outstanding contributions to the development of transonic aerodynamics essential to the engineering design of supersonic aircraft."

Major Gen. Albert Boyd, Commander of Wright Air Development Center, USAF, will be given The Octave Chanute Award "for outstanding contributions to the development of improved aircraft for the U.S. Air Force by personally making evaluation flights in all recent prototype Air Force aircraft, the 'X' series of research aircraft, the Russian-built MIG-15, and numerous prototypes of possible interest to NATO."

The awards will be presented June 23 at the Fifth International Aeronautical Conference in Los Angeles. Details will follow in a later issue.

* * * * *

IAS STUDIES DOCUMENTATION PRACTICES

Director S. Paul Johnston and Librarian John J. Glennon will represent the IAS at a meeting of the Documentation Committee of the Advisory Group for Aeronautical Research and Development, NATO, in Ottawa, June 10-17. On the 17th, Mr. Glennon will attend the annual convention of the Special Libraries Association in Detroit, at which American and European methods of technical documentation, particularly of aeronautical subjects, will be discussed.

* * * * *

HEAT TRANSFER, FLUID MECHANICS CONFERENCE

The 1955 Heat Transfer and Fluid Mechanics Institute is scheduled for June 23-25 at the Los Angeles Campus of the University of California. Myron Tribus, of the Department of Engineering, is General Chairman. The IAS is one of five engineering societies cosponsoring the meeting.

* * * * *

NEW IAS CORPORATE MEMBERS

Arma Division of the American Bosch Arma Corporation, Roosevelt Field, Garden City, Long Island, N. Y.

Aircraft Products Division of Manning, Maxwell & Moore, Inc., Danbury, Connecticut.

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I.A.S. News Notes (con't.)

NECROLOGY

Ivan H. Driggs (F), Chief Scientist of the Naval Air Development Center, Johnsville, Pa., died May 8. He was 61 years of age.

James D. M. Gray (M), of Toronto, Canada, died March 24 at the age of 61.

Arthur B. Schultz (M), of Western Springs, Ill., died May 2. He was 51.

Admiral John H. Towers, USN (Ret.) (AF), President of the Flight Safety Foundation, died in St. Albans Naval Hospital, New York, on April 30. He was 70.

Joe C. Towle (M), Director of Flying Operations, Lockheed Aircraft Corporation, died in a Burbank hospital April 25. He was 49 years old.

* * * * *

NATIONAL MEETINGS CALENDAR

June 20-23 Fifth International Aeronautical Conference, IAS Building, 7660 Beverly Blvd., Los Angeles, Calif.

June 23-25 Heat Transfer and Fluid Mechanics Institute, UCLA, Los Angeles.

Aug. 8-10 National Turbine-Powered Air Transporation Meeting, Olympic Hotel, Seattle, Wash.

Sept. 8-10 Midwestern Conference on Fluid Mechanics and Solid Mechanics, Purdue University, West Lafayette, Ind.

* * * * *

CALENDAR OF SECTION MEETINGS

June 1-- Chicago Section: Glenview Naval Air Station. Display of jet aircraft, 5:30 p.m.; Social Hour at Officers Club, 6:30 p.m.; Dinner, 7:30 p.m. Annual business meeting and election of officers. Navy combat films will be shown.

June 1-- San Diego Section: IAS Building. Classified Technical Session, 8:00 p.m.

June 4-- New York Section: U.S. Navy Special Devices Center, Sands Point, Port Washington, Long Island, N. Y. Picnic lunch, 12:00 noon; Talks on facilities and program, 1:30 p.m.; Tour and demonstrations, 2:15 p.m. Capt. C. H. S. Murphy and Comdr. E. W. Hribar will speak.

June 8-- Niagara Frontier Section: Cornell Aeronautical Laboratory, Buffalo. Tour of wind tunnels and other research facilities, 8:00 p.m.

June 9-- Baltimore Section: The Johns Hopkins University. Social Hour, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:30 p.m. Talk on "Future Transport Designs" by Walter Tydon, Chief Engineer, Fairchild Aircraft Division.

June 14-- Los Angeles Section: IAS Building. Specialist Meeting, 8:00 p.m. Talk on "Boost Period Launching Error" by William M. Bleakney, Senior Staff Physicist, Aircraft Division, Hughes Tool Company.

June 24-- San Diego Section: IAS Building. Joint Meeting and Dinner Dance, Royal Aeronautical Society and IAS.

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IAS News

A Record of People and Events of Interest to Institute Members

Tenth Annual Flight Propulsion Meeting

J. H. Smith, Jr., Assistant Secretary of the Navy for Air, Discusses Planning of Engine and Aircraft Programs

"IN THE AREA between research and production we must have realistic evaluations. We must reach decisions that call for great judgment; we must require that the engineering data be sound and that speculation be clearly marked as such." Thus spoke the Hon. James H. Smith, Jr., Assistant Secretary of the Navy for Air, addressing a large dinner audience of IAS members and guests at the Hotel Carter, Cleveland, on March 11.

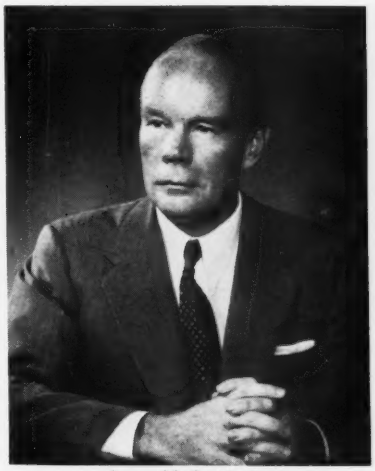
The dinner ended a day of security-closed technical sessions at the Institute's Tenth Annual Flight Propulsion Meeting, attended by more than 650.

Mr. Smith, an Honorary Member and Associate Member of the IAS, is a former Navy flier with three Air Medals and the reserve rank of Captain. He is a former Vice-President of Pan American World Airways, Inc. Currently, he is working on long-range plans for military jet-engine research and development as a member of a three-man board appointed by Secretary of Defense Wilson.

Edward R. Sharp, Director of the Lewis Flight Propulsion Laboratory, NACA, and a Vice-President of IAS, introduced the speaker, whose topic was "Realism in Planning Engine and Aircraft Programs."

"Only a few years ago," began Mr. Smith, "we had definite—I might say fantastic—propulsion problems. All our aircraft programs and especially the high-performance aircraft, in which we were most interested, were ready to roll except that there were no engines."

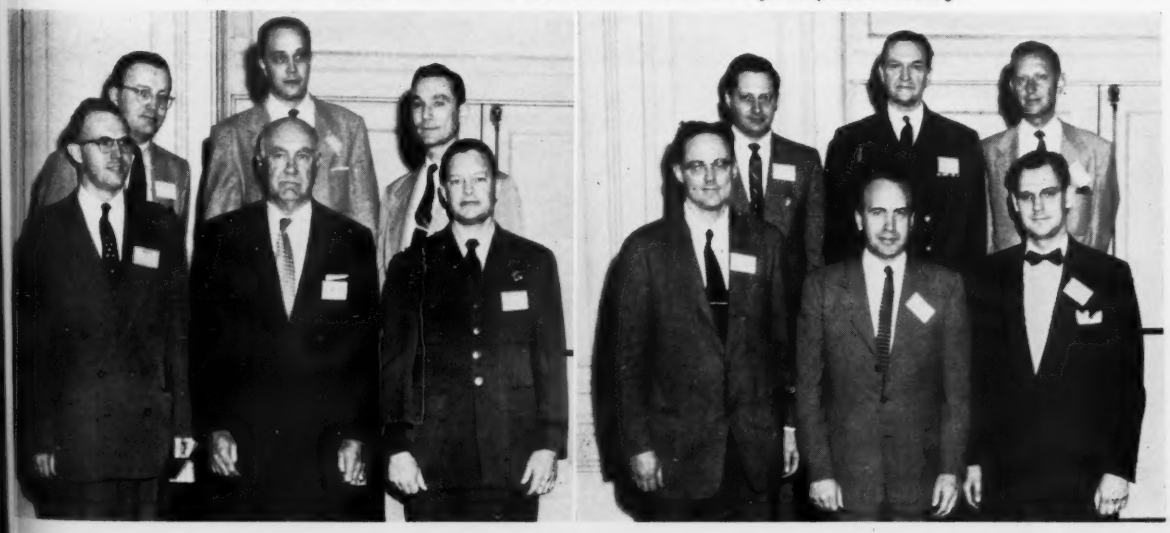
He cited great improvements during the past 6 years in specific fuel consumption, weight/thrust ratio, and frontal resistance of the power unit.



James H. Smith, Jr.

"I shall concentrate on that phase of development in which the payoff is made—the phase in which development leads into production and thus to usefulness to the Fleet," he said. "After the experience of the last few years, the question of what to expect from the engine industry could be answered casually and flippantly by saying, 'All we need are a few good operational

Speakers and chairmen of the technical sessions at Tenth Annual Flight Propulsion Meeting.



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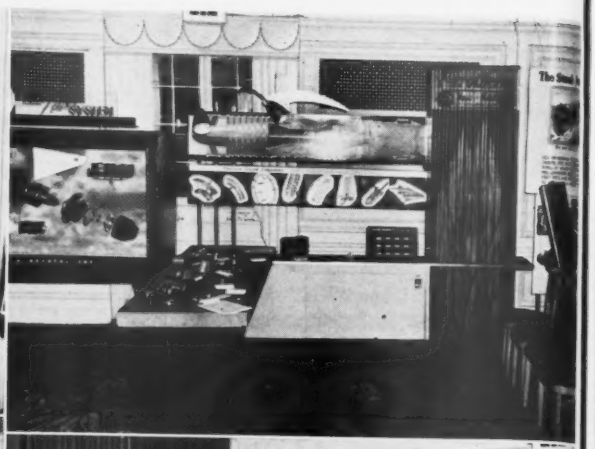

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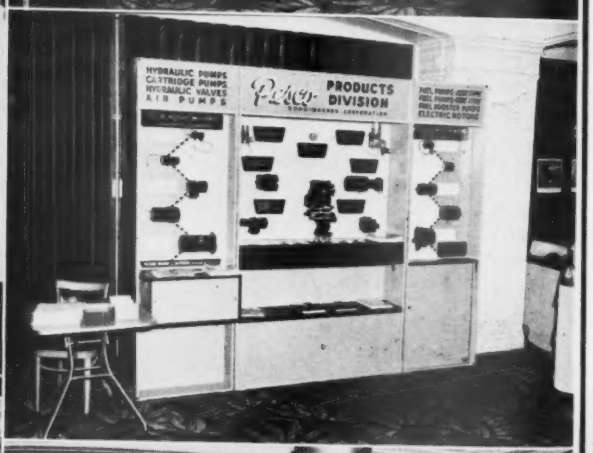
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engines.' The problem is of most serious proportions."

At this point, Mr. Smith discussed the unanticipated difficulties and delays which usually prevent getting a newly designed engine into production on time.

"In order to match the engine with an air frame embodying the latest aerodynamic advances," he said, "we must make sure that our air-frame designs are based upon engines that have given positive evidence of timely, successful fulfillment.

"When we look back over our experience, an analysis shows that the source of our trouble was the common misunderstanding as to the length of time required to develop a jet engine to an operationaliy useful state. The engine contractors show us (the Navy) their availability estimates for their new engine designs, and it seems that in making their time estimates they leave no contingency for the usual developmental setbacks that past performance has proved to be inevitable. Even though the Government is far less competent to do so, it is left to us to implant realism in the hopeful schedules thus submitted.

"However, the air-frame people must use these estimates as the best available data, and they soon come in with very attractive advanced airplane designs based upon the paper performance and dates they have received. These beautiful designs they sell hard and convincingly. In the pervading atmosphere of optimism about the future it is difficult for the Government people to keep level heads to prevent setting up the very kind of situation that we have had in the past.

"It seems as though both the engine and aircraft contractors were content with the short-range view that a big contract in hand, on which delivery is shaky, is better than the chance of a really sound program at a later date. In plainer words, their attitude is: 'Let's get a big contract backlog now and tackle the production problem later.'

"Industry must show a mature and restrained attitude in planning new aircraft models," the Assistant Secretary continued. "This restraint would come in the form of realistic planning and in the selling of future programs based on estimates on which the estimator realizes his reputation is at stake—not on a headlong urge to build up the backlog, come what may. As the engine and air-frame development contracts generally call for payment of costs plus a fixed fee, the contractor is concerned but not financially worried about his mistakes. An indemnity clause might have a salutary effect and might help restrain the contractor's ebullient optimism about his guaranteed ratings and promises of delivery.

"An outstanding performing engine of today, if delivered 3 years late, is as valuable as last year's bird nest. The Government must evaluate as objectively as it can the claims of those bidding for future business, and one of the most important questions is: 'How did this contractor perform in meeting his promises in the past?' A reputation of delivering what is promised when it is promised is something to be highly desired, for it is becoming the *sine qua non* in the Navy's procurement policy."

This year's Flight Propulsion Meeting, which was supported actively by Cleveland's aircraft industry and the NACA, was organized, as usual, by the Cleveland-Akron Section of the IAS. Chairmen of the technical sessions were Major Gen. Edward M. Powers, USAF (Ret.), FIAS, Vice-President—Engineering, Curtiss-Wright Corporation, and Edward C. Wells, FIAS, Vice-President—Engineering, Boeing Airplane Company.

For security reasons, the subjects discussed were not disclosed. Eight papers were presented by the following speakers and coauthors: Norman C. Ruel, of North American Aviation, Inc.; S. C. Himmel and George Basu, Lewis Flight Propulsion Laboratory, NACA; G. W. Lawson and D. C. Prince, Jr., General Electric Company; M. K. Wolfson, General Electric Company; Lt. Col. F. A. Holm, Wright Air Development Command, USAF; W. H. Sens, W. S. Bailey, and Branson Smith, Pratt & Whitney Aircraft Division, United Aircraft Corporation; G. E. Chapman, Allison Division, General Motors Corporation; and Rear Adm. John H. Sides, USN, Office of the Chief of Naval Operations.

Among the members of the Cleveland-Akron Section who took an active part in arranging the meeting were Eugene J. Manganiello, Chairman; William A. Fleming, Program Chairman; Willson H. Hunter, Lewis A. Rodert, Howard F. Powders, E. William Conrad, and Roger F. Weining. IAS Headquarters in New York was represented by Director S. Paul Johnston, Robert R. Dexter, Thomas J. Meskel, Welman A. Shrader, and Joseph P. Ryan.

The reception and displays, sponsored by local manufacturers of the Cleveland area, added considerable interest to the meeting. Hosts for the social hour were American Steel and Wire Company, Ferrotherm Company (Aircraft Components Division), General Electric Company, General Tire & Rubber Company, The B. F. Goodrich Company, Goodyear Aircraft Corporation, Jack & Heintz, Inc., Lear, Incorporated (Lear-Romec Division), Pesco Products Division of Borg-Warner Corporation, The Steel Improvement & Forge Company, and Thompson Products, Inc. Eight of the displays are pictured on the opposite page.

University of Maryland Dedicates Glenn L. Martin Institute of Technology

The Glenn L. Martin Institute of Technology, consisting of eight new buildings erected at a cost of almost $8,500,000, was dedicated at the University of Maryland on March 25. The Institute houses the entire College of Engineering and many of the academic and research departments of the College of Arts and Sciences.

Principal speaker at the ceremony was Lee A. DuBridge, President of California Institute of Technology. Another speaker was Glenn L. Martin, who contributed $2,300,000 toward the project. In addition, he established a sum of $539,215 in the Minta Martin Research Fund of the University of Maryland.

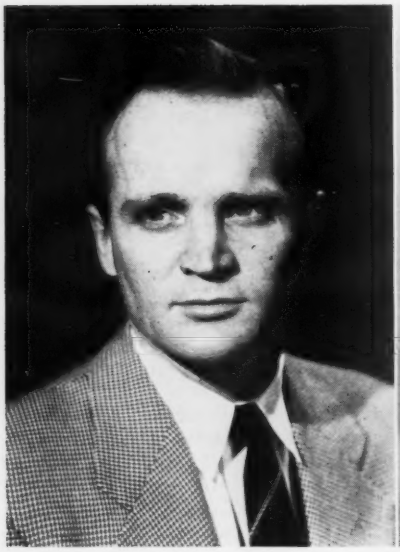
Hugh L. Dryden, Director of the NACA and Past-President, IAS, received the honorary degree of Doctor of Engineering from the University of Maryland during the dedication.

One of the new buildings is the Aeronautical Laboratory, where the Wind-Tunnel Operations Department conducts research and development on aeronautical projects on a year-round basis. Projects are sponsored by such organizations as The Naval Ordnance Laboratory, Camp Detrick, The Glenn L. Martin Company, McDonnell Aircraft Corporation, and Chance Vought Aircraft, Incorporated. Sponsors pay for the use of the wind tunnel at the rate of approximately $100 per hour, which yields sufficient income to meet all financial needs of the laboratory.

A full-time staff of 13 people, augmented by part-time student assistants, works with engineers from the sponsoring organizations. Recent projects completed at the wind tunnel include aerodynamic investigations of airplanes, missiles, mines, parachutes, etc.

Honors for von Kármán

Theodore von Kármán, HFIAS, Chairman of the Advisory Group for Aeronautical Research and Development, NATO, has received the USAF's highest civilian award and two French honors within recent months. The Exceptional Service Award for "contributions to the achievement of the advanced weapons systems" while Chairman of the Scientific Advisory Board was presented to him by the Air Force. The French Academy of Sciences elected Dr. von Kármán a full foreign member, an honor that has been accorded only 14 non-French scientists. The French Legion of Honor elevated him to its highest rank—Commander.



Warren J. North

William B. Browne

David G. Powell

Flight-Test Engineering Fellowships Awarded

Two former military pilots have been selected by the IAS for Fellowships in Flight-Test Engineering at Princeton University. The 1955 winners are Warren J. North, an aeronautical research scientist and research pilot at Lewis Flight Propulsion Laboratory, NACA, and William B. Browne, who graduates this month from North Carolina State College with a B.S. in mechanical engineering (aero option).

The 2-year Fellowships are provided by an anonymous donor and administered by the IAS. Entering Princeton next fall, the winners will take a program of graduate courses designed for flight-test engineers of the Navy and Air Force.

Mr. North, 32 years old, has been employed at Lewis Laboratory since September, 1947. He is a Technical Member of the IAS. A former bomber pilot and flight instructor in the Air Force, he has accumulated 3,000 hours' flying time in eleven types of planes. His engineering work at Lewis has included wind-tunnel tests on turbojet engines, performance analysis of ram-jet missiles, and investigation of aerodynamic noise. As an NACA pilot, his work has been concerned largely with ram-jet and turbojet-icing research programs. He has been author or coauthor of six NACA technical papers.

Mr. North attended the University of Illinois before joining the Air Force in 1943. He received his B.S. in aeronautical engineering from Purdue University in 1947. He is due to receive a master's degree in aeronautical engineering this month from Case Institute of Technology.

Mr. Browne, 26, is a former jet pilot who attended the University of North Carolina before enlisting in the Navy in April, 1948. He has logged 750 hours in the air. He gained experience as a flight-test technician through summer jobs with Chance Vought Aircraft, Inc., and Grumman Aircraft Engineering Corporation.

The IAS Board of Award which chose the Fellowship winners consisted of Hugh L. Dryden, Director of the NACA; Roger Wolfe Kahn, Service Manager and Test Pilot, Grumman Aircraft Engineering Corporation; and S. Paul Johnston, Director, IAS.

The first of these Fellowships in Flight-Test Engineering was awarded last year to David G. Powell, a 1954 graduate of Princeton. He is to receive his master's degree in aeronautical engineering this month and expects to enter the aircraft industry immediately.

Purdue Lists Conference on Fluid, Solid Mechanics

The Second Midwestern Conference on Solid Mechanics and the Fourth Midwestern Conference on Fluid Mechanics are scheduled for September 8–10 at Purdue University, West Lafayette, Ind.

The IAS will be one of six cosponsors. Program for the meetings will be announced about August 1, after all papers submitted have been reviewed by the editorial committees. June 10 is the closing date for manuscripts.

Four Purdue engineering professors head the committees for the conferences. Paul F. Chenea is Chairman of the Organizing Committee; J. L. Waling, Arrangements Committee; J. L. Bogdanoff, Editorial Committee for Solid Mechanics; and R. C. Binder, Editorial Committee for Fluid Mechanics. The first three are attached to Purdue's Division of Engineering Sciences; Mr. Binder is with the School of Mechanical Engineering.

Besides the IAS, the sponsoring societies are the American Institute of Chemical Engineers, American Physical Society, American Mathematical Society, American Society of Mechanical Engineers, and Society for Experimental Stress Analysis.

Papers to be considered for presentation have been invited from professional engineers working in the fields of kinematics, dynamics, vibrations and waves, mechanical properties of materials, stress analysis, elasticity, plasticity, fluid mechanics, and thermodynamics.

Nuclear Development Associates, Inc., Joins IAS

Nuclear Development Associates, Inc., of 80 Grand St., White Plains, N.Y., has become a Corporate Member of the Institute of the Aeronautical Sciences.

Founded in 1948, the company is one of the oldest independent nuclear engineering firms in the United States. Its main facility, located in White Plains, is a 55,000-sq.ft. building with a well-equipped experimental shop and laboratory. Nuclear Development Associates owns a 1,100-acre experimental station in Pawling, N.Y., north of White Plains. The firm has 130 employees.

The company's principal activity is the design and development of nuclear reactors. It is carrying on work in the field of industrial power and has been associated, either directly or indirectly, with the aircraft nuclear propulsion program since the company's inception. Other NDA projects cover a wide range of high-performance applications, from continuous casting of steel to design of computing and data-handling techniques, systems, and equipment.

A wholly owned subsidiary, Advance Technology Corporation, is concerned with the design of nuclear facilities.

Langley Gold Medal Presented to Hunsaker

Jerome C. Hunsaker, Chairman of the National Advisory Committee for Aeronautics and First President of the IAS, was awarded the Langley Gold Medal of the Smithsonian Institution on April 14. Chief Justice Earl Warren, acting in his capacity as Chancellor of the Board of Regents of the Smithsonian, presented the medal at a dinner marking the fortieth anniversary of the NACA. Present and past members of the NACA were guests of honor at the affair, held in the Great Hall of the Smithsonian in Washington.

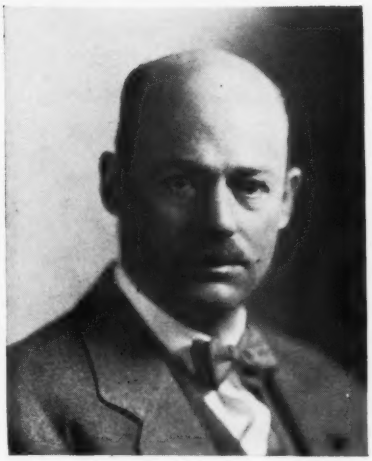
Dr. Hunsaker was chosen to receive the Langley Medal, according to the citation, "in recognition of your unique and superlatively important contributions to aeronautics as a distinguished designer of aircraft, as the creator of a great center for instruction in aeronautical engineering, and as the scientific genius under whose leadership the present-day National Advisory Committee for Aeronautics has become the world's greatest scientific aeronautic research organization."

Dr. Hunsaker has been a member of the NACA since 1938 and Chairman since 1941. The Langley Medal has been awarded only eight times since 1909. The last recipient was the late Joseph S. Ames, in 1935.

ARDC Asks Engineers for Ideas and Inventions

The Air Research and Development Command is intensifying its search for new ideas that might lead to dramatic strides in the development of aircraft, weapons, and equipment. Even revolutionary ideas will receive a sympathetic hearing, the ARDC announced recently. Hidden among hundreds of futile ones, it is thought, there may be an innovation that will lead to a technological breakthrough.

Lieutenant Colonel Melville W. Beardsley, MIAS, has been appointed to the newly created post of Assistant for Innovations which is the focal point for receiving and studying ideas contributed by industry, universities, and private individuals engaged in research.



Jerome C. Hunsaker

Colonel Beardsley and his staff will attempt to reduce the time lag between the conception of a basic idea and its adoption by the Air Force. In the past, delays have been caused by absence of communications between the inventor and the ultimate user, by the user's inability to realize the potential value of a proposed device, and by the high cost of preparing a proposal to the Air Force when no definite military requirement existed.

The ARDC said all proposals submitted will be evaluated by experts in the branch of technology concerned. They should include a description of the innovation, with estimates of expected performance. Potential value should be explained in terms of increased performance, saving of weight or money, easier maintenance, etc. Correspondence should be addressed to the Assistant for Innovations, RDTE, Headquarters, Air Research and Development Command, Box 1395, Baltimore 3, Md.

Necrology

John H. Higman

John Henry Higman, MIAS, Research Engineer, Grumman Aircraft Engineering Corporation, died April 17 following an operation for ulcers. He was 29 years old.

Born in Jersey City, N.J., Mr. Higman was graduated from Rensselaer Polytechnic Institute in 1946 and served in the Navy before joining Grumman. He received his Master of Aeronautical Engineering degree from RPI in 1947 and was advanced to full membership in the Society of the Sigma Xi. He lived in Floral Park, N.Y.

Chi-Teh Wang

Chi-Teh Wang, AFIAS, Professor of Aeronautical Engineering at New York University, died April 22 at the age of 35. He had suffered 2 years from Hodgkin's disease.

Dr. Wang was known for his research on aeroelasticity, aircraft structures, plates and shells, and compressible flow. He was working on aerodynamic flutter under Air Force sponsorship at the time of his death. He served on the editorial committee of the JOURNAL OF THE AERONAUTICAL SCIENCES as a specialist in structures and materials.

Born and educated in China, Dr. Wang came to this country in 1941 and assumed American citizenship. He held a Master's degree in aeronautical engineering from Rensselaer Polytechnic Institute, a Master's degree in mathematics from Brown University, and a Doctor of Science degree from Massachusetts Institute of Technology. He taught at the University of Akron before joining the N.Y.U. staff in 1946.

News of Members

▸ **Martin E. Barzelay** (M), Professor of Aeronautical Engineering, Syracuse University, heads a research group studying the weakening effect of high skin temperatures induced by aerodynamic heating during supersonic flight. The NACA-sponsored program seeks to determine the pattern of temperature distribution in aircraft structures.

▸ **Neil Burgess** (M), Aircraft Gas Turbine Division, General Electric Company, has been appointed to the NACA's Subcommittee on Aircraft Fuels.

▸ **David Cochran** (M), General Manager, Aircraft Gas Turbine Development Department, General Electric

(*Continued on page 84*)

Robert E. Gross
President
IAS

IAS

Fifth

Welcome Aboard!

As this issue of the *Review* comes from the presses, many of the delegates of the Royal Aeronautical Society will be on their way to America. By mid-June, all will be here and will be concentrating on Los Angeles. Every member of the Institute joins in welcoming them to our shores. We are all looking forward to a continuation of the pleasant and profitable associations that have been formed over the years since such conferences have been held.

Many of those who will meet in Los Angeles in both the British and American groups will be "Five-Timers." They participated in the tentative beginnings in London in 1947 and New York in 1949. They well remember the famous trek to Brighton in '51 and the hospitality of London in '53. Once again it is our turn, and it is our hope that our visitors will carry back with them pleasant memories of the technical and social programs that have been arranged for them.

For the planning and arrangements of the activities in Los Angeles, San Diego, and San Francisco, the Institute owes a great debt to the

RAeS

Conference

N. E. Rowe
President
RAeS

local Sections of those cities. Their officers and various subcommittees have been meeting for many months, and they have carried the major part of the load of local arrangements for the Conference. The IAS western office staff has furnished support, and New York headquarters set general policy, worked out the programs of technical papers, and acted as the liaison channel with the RAeS; but the Sections themselves have put tremendous energy into making the Conference a success. A vote of thanks from all of us goes to the officers and members of the three California IAS groups for a good job well done.

With the ground work so well laid, the outcome of the Conference is assured. There remains now only the pleasant business of welcoming our visitors from overseas and of making them feel at home in this strange and barbaric land. Fortunately, many of them are Old American Hands and know something of our curious ways, but for the newcomers we bespeak the cooperation of all our members to make them feel as much at ease and as much at home here as they have done for us on our visits to The Other Side.

S.P.J.

BASES UNLIMITED

A helicopter view of the XF2Y-1 Sea Dart during the high-speed portion of a take-off run.

By Ernest G. Stout*

Convair, A Division of General Dynamics Corporation

Introduction

Weapon system analysis has become an increasingly common expression in recent years because of the extreme complexity of modern weapons and their interrelated employment. In years past it had been customary for military staffs to do the major share of war planning, and in only few instances was the aircraft contractor aware of the underlying policy planning or broad concept development which led to the generation of specific aircraft requirements. The procuring agencies of the military establishment would contract with industry for materiel designed to meet the specific requirement involved, and the contractor's responsibility was complete when his aircraft performed in accordance with the specification and a proper spares and technical service organization was established.

With the advent of supersonic speed, nuclear and thermonuclear weapons, and the elaborate networks of electronic aids for both guidance and detection of these weapons, the military has sought the assistance of highly trained industry and educational groups to supplement the traditional military planning staffs in the evolution of integrated systems. The military contractor now has an added responsibility not only of building a required piece of hardware to meet a certain military specification but of analyzing in detail how this component is to be integrated into an overall system concept involving close coordination with other weapon components, their deployment, logistic support, and impact on the national economy.

Presented at the CAI-IAS International Meeting, Montreal, Can., Oct. 14–15, 1954.

* Staff Engineer.

Preceding the current popularity for such procedures by more than a decade is an excellent example of concept planning which, due to its early conception and implementation, has all of its essential components in being and on actual full-scale flight status. Within the limitations of military security this paper will outline the evolution of this integrated system that was founded on the fundamental premise that the immobility, time of preparation, and natural concentration inherent in the land-basing of air power in advanced areas must be supplemented by a system completely divorced from the airstrip.

While a full weapon system analysis assigns detail quantitative values to the many parameters involved, this paper will be limited to a discussion of the prime air-frame components involved and a qualitative assessment of their potential with regard to deployment and economy of operation.

Unlimited Base Concept

Historical Background

Beginning with Glenn Curtiss in 1911 and continuing up to the start of World War II, many groups of manufacturers and military leaders showed great interest in the inherent advantages of water-based aircraft, and a considerable percentage of aircraft development effort went into perfecting this branch of aviation. This interest was rewarded with considerable success that saw flying boats overcome the Atlantic for the first time and go on to pioneer all the world's routes of aerial commerce. It appeared that the flying boat was firmly established, and the slight performance deficiency, when

compared with its wheeled counterpart, was lightly passed off as of no consequence when the increased safety and efficiency of operation were given due weight.

This false sense of security prevailed in spite of the warnings of a few who foresaw the inevitable evolution of refined aerodynamic design and increased power and the incompatibility of the "winged boat" concept to both of these advancements. History records that the inevitable did occur, and in the great era of aeronautical development induced by World War II the flying boat, with its cumbersome hull and low performance, was relegated to a minor role.

Recognizing that a case of acute design stagnation in the hydrodynamic field was in danger of eliminating a weapon of great potential, a small group of individuals in the Bureau of Aeronautics of the Navy, the National Advisory Committee for Aeronautics, and Convair resolved to do something about the backsliding seaplane. At this point the entire art of seaplane hull design was confined to the shaded area of Fig. 1 where the influence of hull length/beam ratio on the hull load and load-resistance ratio at hump speed is plotted.

In Fig. 1

L = length of hull
b = beam of hull
Δ = load supported by hull
R = total hydrodynamic resistance
w = density of water
C_Δ = nondimensional load coefficient ($= \Delta/wb^3$)
C_R = nondimensional resistance coefficient ($= R/wb^3$)
Suffix H = at hump speed

It can be noted in Fig. 1 that the short stubby hulls of low length/beam ratio placed a severe limitation on the potential load-carrying ability and efficiency of the planing surfaces. Previous attempts to increase the performance through increase in the fineness ratio of the hulls were always met by a rapid deterioration in hydrodynamic stability which resulted in violent porpoising and therefore no usable increase in loading. The classic Froude towing tanks and available analytic theories were not capable of solving these complicated dynamic problems, resulting in a technical impasse.

With the recognition that the first requirement was to develop a simple but accurate technique for determining the complex dynamics of discontinuous functions in two media, an extensive survey of all possible methods for accomplishing this basic task was initiated. After much investigation and analysis the excellent work in England of Coombes, Perring, Johnston, and Hutchinson[1, 2] came to the attention of the author. Their investigations were concerned with the development of a direct research technique through the employment of dynamically similar models. Since the principal problem to be encountered in the new hydrodynamic research program had been recognized to be one of complex dynamic functions, this procedure appeared to be ideal.

Much had to be done to bring the dynamically similar model technique to its present high degree of dependability and accuracy. It is interesting to note that since its introduction in the United States in 1938[3] by the author, it was immediately successful and has resulted in steady improvement in water-based aircraft performance. In its first application, although crude by present standards, the dynamic model made possible a 60 per cent increase in the operational gross weight of the famous Coronado flying boat at a critical phase in the war effort. Because of their initial success and the urgency of the war, the dynamic models were employed almost exclusively for the improvement of existing seaplanes, and little time was available in the towing tanks for basic research programs. In view of the crowded facilities and a desire to eliminate from the models all restraint, which was obscuring certain essential observations, the Convair Hydrodynamics Research Laboratory in 1943 initiated a program to develop free-body, dynamically similar models to be self-propelled and remotely controlled by multichannel radio. This project was highly successful, and by May, 1945, the techniques and procedures for operating these free-flight models had been demonstrated, and a complete program of correlation studies with a full-scale flying boat was completed.[4]

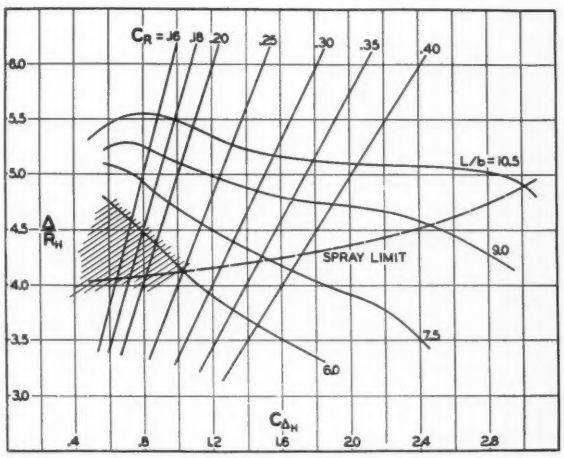


FIG. 1. Influence of length/beam ratio on the hull load and load-resistance ratio at hump speed.

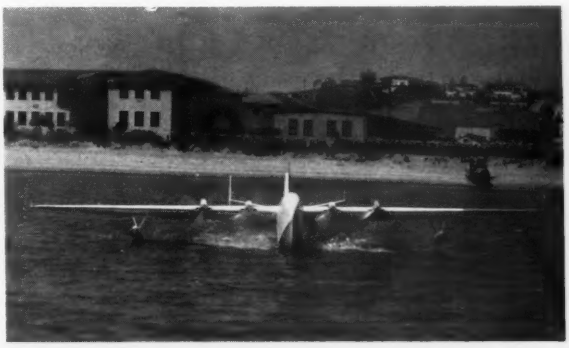


FIG. 2. The 21-ft. span, powered dynamic research model controlled by radio. Wing and tail are removable for incorporation on hulls of various configurations.

Subsonic Research

With the firing of the first nuclear weapon in 1945 it finally became apparent to all that an era of warfare had closed and a new era had dawned. The Hydrodynamics Research Laboratory had been working since 1938 on a program to develop efficient high-speed, water-based aircraft so that the potential for full mobility of air power could be realized—the events at Hiroshima and Nagasaki made the accomplishment of this task a must. Massed force, tied to large fixed-base complexes, was destined to become a thing of the past, with future emphasis being directed toward dispersion and mobility. Armed with a practical research tool for rapidly developing new and radical hydrodynamic sustention systems, the research laboratories were fortunately in a position to prosecute vigorously a program of research and development at this critical period in world history.

In view of the urgency associated with the nuclear threat a thorough review of possible requirements and concepts was undertaken so that a long-range plan could be established to guide the development efforts necessary to build up a completely integrated forward area striking force that would be free of advance preparation of fixed bases. It was obvious that high-speed logistic support would be required for any system; however, the really significant conclusion reached was that means must be devised to attain tactical aircraft (interceptors, fighters, and fighter-bombers) which would be a match, performancewise, for their land-based counterparts if any such system was to be effective. It was recognized that this would be an enormous task inasmuch as no one seriously believed it possible to water-base this category of aircraft without extensive compromise.

As a result of the successful experience during the war in increasing the loading of existing flying boats and the availability of the highly refined free-flight, radio-controlled dynamic model technique it was decided to proceed immediately into the problem of the load-carrying seaplane while studying possible approaches to the tactical concept. Under Navy sponsorship and utilizing the large 21-ft. span, radio-controlled research model shown in Fig. 2, Convair initiated an investigation of the promising relationship between the influence of hull beam and length on the load-carrying ability and seaworthiness of seaplane hulls. With the discovery of the key to satisfactory stability and spray performance at very high loadings, the remainder of Fig. 1 (outside of the shaded area) rapidly became available to the design of high-performance seaplanes. (The details of this intensive study have been covered adequately in references 5 and 6 and will not be repeated here.)

Rapid exploitation of this vast new area of hydrodynamic design potential was undertaken as illustrated in Fig. 3. In April, 1946, less than a year after the start of the above research program, a complete design proposal for a large high-performance seaplane was submitted to the Bureau of Aeronautics, and a contract was let for its construction the following month. As noted in Fig. 3, this initial research effort resulted in a net increase of over 250 per cent in hull load coefficient, which is actually equivalent to over 300 per cent when it is considered that the listed loadings for the World War II seaplanes are for extreme wartime overloads, whereas the C_Δ of 2.58 represents a conservative normal design load. A direct result of this significant increase in hull efficiency was a marked reduction in hull frontal area and a proportionate reduction in aerodynamic drag. This was of sufficient magnitude to justify, for the first time, the incorporation of very low power loading in a seaplane and thereby realize a radical increase in aircraft performance. This is graphically portrayed in Fig. 4 where the power loading in pounds per brake horsepower of the large R3Y seaplane transport is noted to be actually less than the best fighters of World War II. With this accomplishment it is safe to say that the first-phase, or subsonic, program of advanced hydrodynamic research was successful in its attempt to foster a new concept of seaplane design.

Transonic Research

As the subsonic research program for the Navy progressed and sufficient design criteria became available to allow a high-performance seaplane to be proposed which used fully the new turbine-propeller engine, additional time became available to consider the next phase of the overall concept. Inasmuch as the turbojet engine was rapidly becoming available and the feasibility of transonic aircraft was established, it was determined that means must be devised to assimilate these power-plant and aerodynamic developments into the water-based concept. The adaptation of transonic aircraft design to water-based operation, without sacrificing any of the high standards of hydrodynamic performance which were introduced into seaplane design during the first stages of the research program, indicated that a radical approach was necessary. Armed with the extremely versatile and successful dynamic model technique, it was felt that this task could succeed inasmuch as many configurations and modifications could be investigated thoroughly with a minimum expenditure of time and funds. By eliminating the necessity for a costly full-scale program in order to establish gradually each step of the development, it was possible to plunge immediately into radical concepts even though the chance of complete success for any one proposal was remote.

Rapidly the dynamic model and the research techniques were adapted to the jet age. Smaller and lighter radio gear was designed, a high-speed towing launch was procured, and small jet engines were developed and adapted to power the speedy models. Fires were frequent—controls failed and spectacular crashes were commonplace—but evidence was piling up, and in the short span of less than a year jet model testing was reliable, accurate, and routine. The Navy Department, alert to the potential represented by these developments, threw its support fully behind this

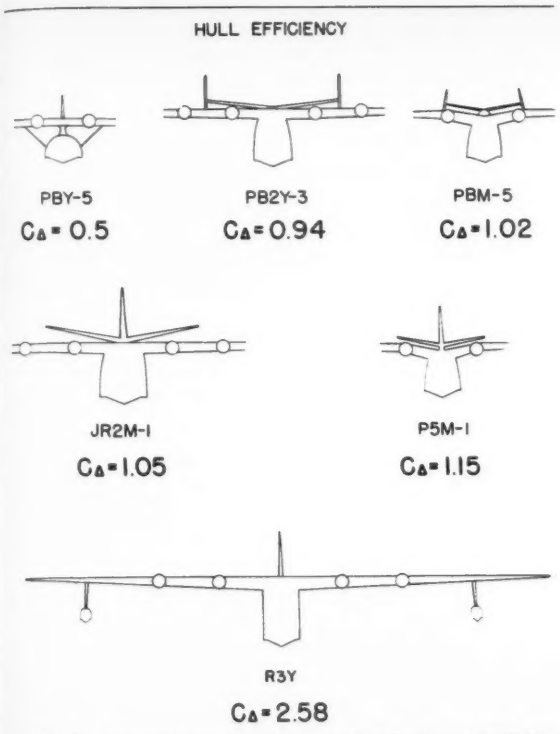


FIG. 3. A comparison of maximum design hull load coefficients for several contemporary seaplane designs including the high L/b ratio R3Y.

FIG. 5. A radio-controlled dynamically similar free-flight model of a transonic water-based fighter during a high-speed planing test run. This model is self-propelled with dynamically similar pulse-jet engines.

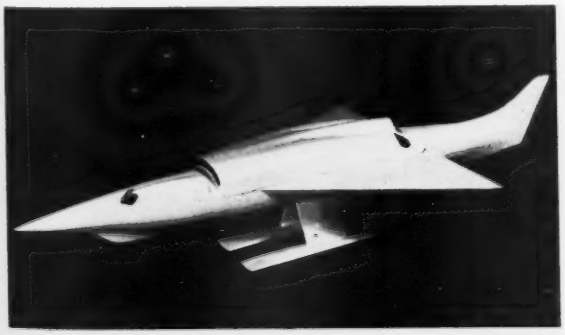


FIG. 7. A delta-wing, supersonic configuration incorporating the NACA hydroski.

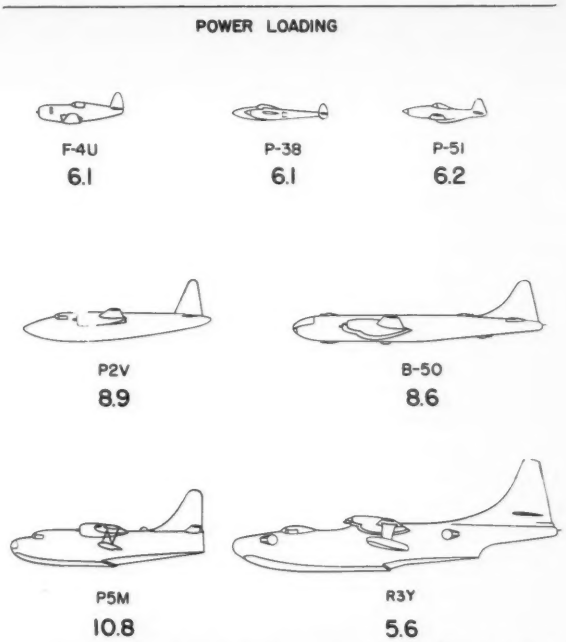


FIG. 4. A comparison of design power loading (lbs./b.hp.) for several contemporary aircraft including the high L/b ratio R3Y.

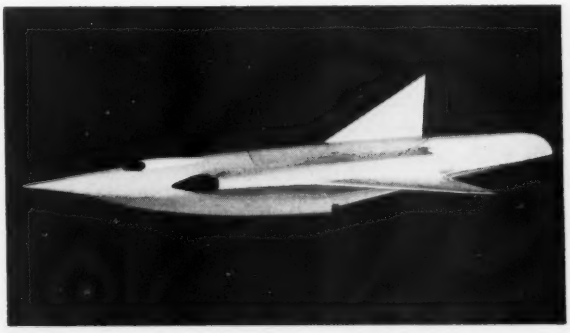


FIG. 6. A dynamically similar flying model of a delta-wing, supersonic blended-hull configuration.

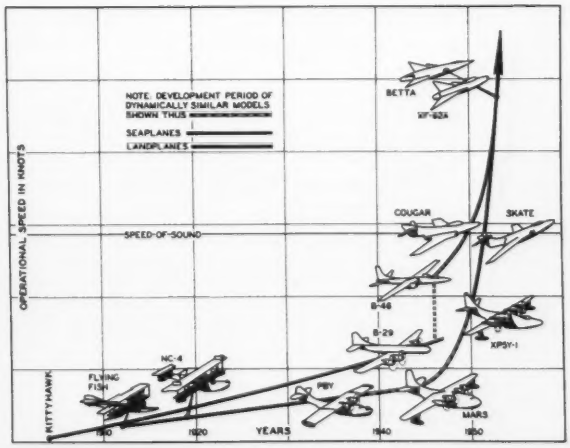


FIG. 8. Relative operational speed of landplanes and seaplanes.

program by generating a requirement for a two-place transonic seaplane night-fighter and providing the necessary funding. Under the highly classified code name Project Skate there gradually evolved a new look in seaplane design consisting of clean unbroken lines, high critical Mach Number sections from centerline to tip, submerged engines, no wing-tip floats, and—above all—hydrodynamic characteristics equal to, or exceeding, the best attainable by conventional means. (The technical aspects of this development are fully discussed in references 6 and 7.)

At the close of the program it became apparent that a transonic water-based aircraft could be developed to meet or exceed any requirement for this range of speed. Using inexpensive dynamic models, the equivalent of nine prototype aircraft had been completely developed and flight tested during the period normally required to produce and test one prototype full scale. Fig. 5 shows a jet-powered flying model of the final configuration that met fully the exacting requirements for a transonic seaplane night-fighter.

The technical feasibility of incorporating jet power plants into the most advanced aerodynamic configurations without compromise to performance or hydrodynamic efficiency was readily established by this program, and the ultimate success of the unlimited base concept was assured from a research standpoint. Unfortunately, it took much more time for such a radical approach to be accepted fully by development and procurement personnel who had become convinced, and justifiably so, that the accomplishment of such a task was highly improbable. A contract to build the water-based transonic night-fighter was eventually placed; however, valuable time had been lost, and this aircraft was destined to become operational at a time when transonic aircraft would be phasing out because of the inevitable development of full supersonic flight. Because of fear of this trend and the wish not to allow hydrodynamic development to falter again, the interest of the research program was turned immediately to the problems of water-basing supersonic aircraft.

Supersonic Research

Following the philosophy that evolved a water-based transonic aircraft in record time, the first step in the supersonic program was to determine an optimum aerodynamic configuration and then to water-base this ideal form without compromise to the performance. In 1945 Convair had initiated a study of triangular or delta wings in a search for a sound, basic approach to an aerodynamic configuration that would incorporate desirable characteristics at airplane speeds in the range of Mach Numbers 1.0 to 2.0. These studies definitely showed a tailless 60° delta-wing configuration to be superior to conventional sweptback configurations from the standpoint of drag, stability, and control. An Air Force contract was awarded for a fighter of this form, and in September, 1948, the first delta-wing aircraft in the world, the XF-92A, was successfully flown at Muroc, Calif. In view of this broad background and experience with the world's first delta-wing aircraft, it was natural that such an aerodynamic configuration should be employed in the supersonic hydrodynamic research program. Through the use of the dynamic model and utilizing the highly efficient delta wing of the XF-92A, a supersonic water-based research program designated Project Betta was initiated under Navy sponsorship.

The hydrodynamic configuration offering the least compromise with statics and low-speed operation appeared to be the blended-hull, and, in view of the broad background of experience with this form of body during Project Skate, it was selected for the preliminary studies. Considerable evidence was available which indicated many inherent advantages of this type of design, such as adequate static displacement, excellent stability and spray, facility for burying the engines within the structure of high Mach Number section of low thickness, and—of special interest for supersonic application—the inherent static transverse stability attained on the water without recourse to auxiliary wing-tip floats. The dynamically similar flying model, shown in Fig. 6, presents the result of applying this line of thought to a basic aerodynamic configuration incorporating a 60° delta wing. It will be noted that the lines layout produced a hull of high length/beam ratio capable of supporting high load coefficients for a minimum of beam and hence retractable step mechanism. A wind-tunnel model of this configuration indicated that the desired aerodynamic cleanness and performance were attainable.

Unfortunately, even though the hull deadrise had been increased to 60°, the blended-hull concept was unable to cope with the high impact loads to be encountered in the desired open-sea operating conditions. Coupled with the problem was an inherent characteristic of the delta wing which requires extremely large angles of attack to develop the necessary lift for take-off and landing. The high length/beam ratio hull with its long afterbody resulted in a configuration that made the attainment of this condition appear insurmountable by any reasonable means. At about this time preliminary results of a research study conducted by the Hydrodynamics Division of the NACA at Langley Field, Va., became available. This study was concerned with basic research on very highly loaded planing surfaces known as hydroskis, and the preliminary results indicated great promise for this device. The hydroski, by virtue of its high loading and small area, offered a practical solution to the imposing problem of very high speed operation in open seas. Of greater significance, however, was the potential for retracting these surfaces completely within the envelope of the ideal aerodynamic form and then extending them on struts to a position that allowed the high angles of attack necessary to develop full lift on the delta wing.

Exploitation of this new principle was rapid. Starting with the classic ski of the NACA, shown in Fig. 7, a series of 32 ski configurations were tested in the short span of 3 months. This concentrated program of ap-

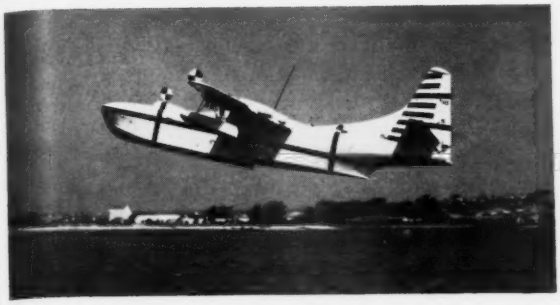


FIG. 9. A radio-controlled dynamically similar flying model of the XP5Y-1 seaplane incorporating a high length/beam ratio hull.

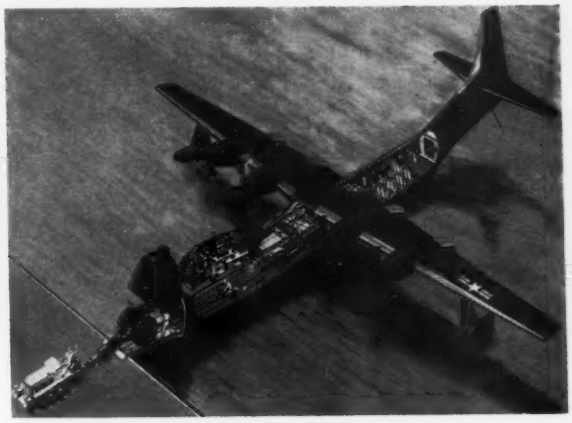


FIG. 10. Cutaway of the R3Y-2 Bowloader logistic seaplane showing the loading of heavy military equipment.

FIG. 11. Head-on view of the R3Y-2 Bowloader showing the clean interior and the loading ramps.

FIG. 12. Aerial view of the R3Y-2 Bowloader during an actual operation on an unprepared beach where military equipment and personnel are being off-loaded.

FIG. 13. Aerial view of the R3Y refueling a division of four fighters: The fighters are surveying the aerodynamics of the refueling positions. The R3Y is designed to carry four refueling drogues and reels.

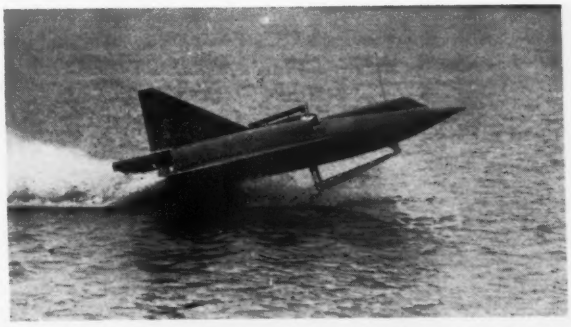


FIG. 14. A radio-controlled, jet-propelled dynamically similar free-flight model of the XF2Y-1 Sea Dart during a test operation.

FIG. 16. The XFY-1 Pogo Stick vertical take-off and landing fighter during a vertical flight operation.

plied research resulted in sufficient design data to develop a practical hydroski system that met all of the exacting requirements for supersonic application. The concept of giving aerodynamics first priority and then developing radical new hydrodynamic sustention systems through the use of dynamically similar models made it possible to close the gap between land-based and water-based performance, and the old classic argument of "land plane vs. seaplane" was definitely put to rest.

The evolution of flight since the Wright brothers, graphically summarized in Fig. 8, vividly portrays the bitter struggle of water-based aircraft development. As indicated, the ultimate objective had been attained where military planning could base air power in accordance with the dictates of strategy only, without regard to technical deficiencies. The full implementation of the unlimited base concept was now possible. The pending obsolence of the water-based transonic night-fighter, previously discussed, now forced the findings of the supersonic Project Betta into the breach. This timing was opportune; without delay the basic contract was amended, and the supersonic seaplane was born.

COMPONENT DEVELOPMENT

R3Y Tradewind

Concurrent with the successful research program previously described was an intensive program of design

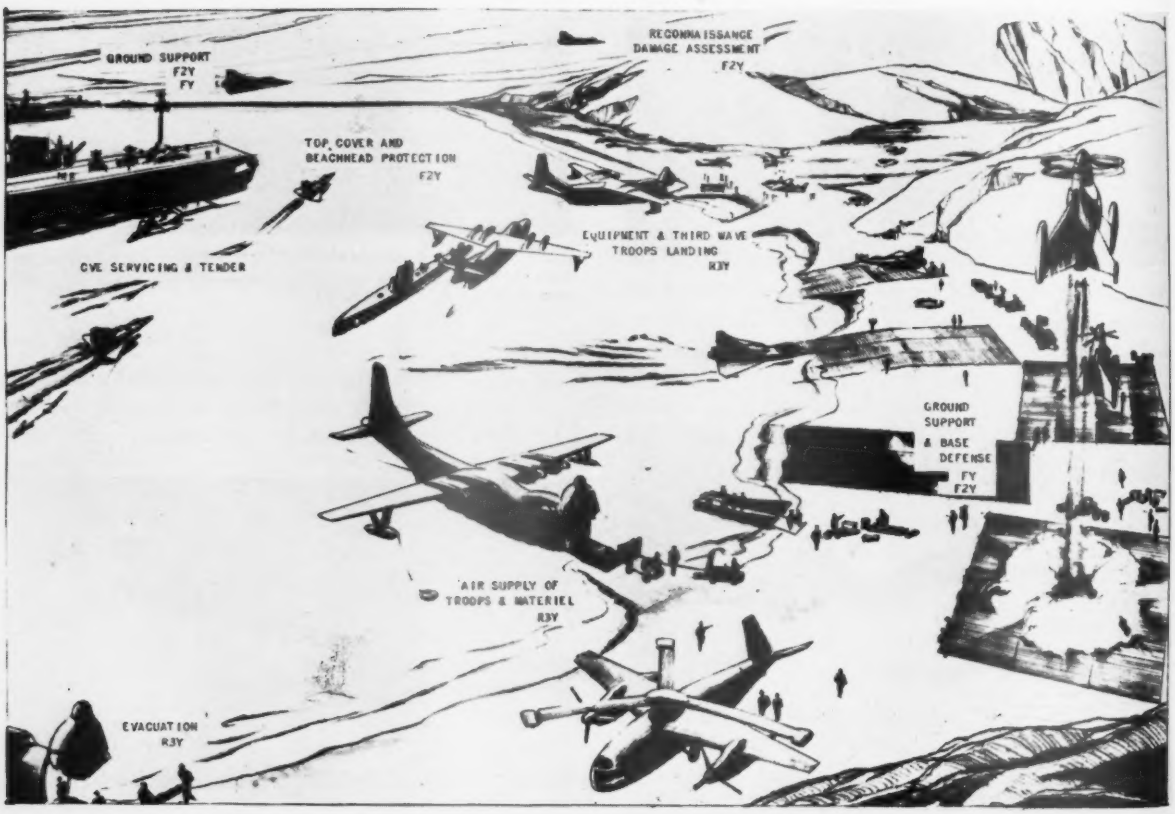


FIG. 17. An artist's sketch of the components and equipments involved in the forward area advanced base concept.

studies pointing toward the practical implementation of the concept of a forward area striking force that could operate without advance preparation of bases. As new evidence became available from the research program, these data were incorporated into specific designs for meeting the integrated requirements for logistic and tactical aircraft. Inasmuch as means for increasing the load-carrying ability and performance of conventional-type seaplanes was the first significant product of the research program, and since a large logistic-support aircraft would probably take the longest to develop, the initial effort was directed to this end.

In December, 1945, the Navy sent out invitations to bid on a new high-performance seaplane to be powered by turboprops and designed for antisubmarine warfare. This appeared to be an ideal opportunity to propose the significant improvements inherent in the new high length/beam ratio hulls. With the logistic transport potential of such an aircraft well in mind, the radically new concept of multicellular watertight integrity was introduced into this design. While not essential for the antisubmarine warfare mission, the incorporation of multicellular hull construction completely freed the hull interior of massive watertight bulkheads—a condition essential to ultimate use as a practical logistics transport.

This competition was won by the high-speed, turboprop-powered XP5Y-1 seaplane, shown being flight tested on the radio-controlled dynamically similar model in Fig. 9. First flown in April, 1950, it was the first to utilize the highly efficient new hull. In the meantime, the requirement for a high-speed, water-based logistic transport had been recognized. In view of the suitability of the XP5Y-1 type for this mission, a production contract was let in August, 1950, for eleven of this type of seaplane, to be known as the R3Y-1. In order to exploit the full advantage of straight through unobstructed loading, inherent with multicellular construction, and to free the seaplane from the necessity of previously prepared ramps, U docks, and associated handling equipment, a proposal was submitted for the ultimate in water-based logistic transport—a bowloading "flying LST." The merits of this proposal were immediately recognized, and in February, 1953, an amendment to the R3Y-1 contract was processed, making the last six of the eleven airplanes into bowloading transports known as the R3Y-2.

The versatility of this aircraft is immediately apparent from the artist's cutaway shown in Fig. 10. Here we see the aircraft loading items of equipment heretofore considered impractical for a water-based transport. As a matter of fact, the large 80 by 100 in. bow opening and the 88 ft. of unobstructed interior will accommodate up to three $2^1/_2$-ton trucks or three 155-mm. howitzers with a track-type tractor prime mover. As a troop transport, the R3Y-2 will carry 103 fully equipped troops or, for evacuation, 92 litter patients with provisions for 12 attendants. With performance comparable with a World War II fighter and the ability to operate from simple finger piers or the beach itself, it

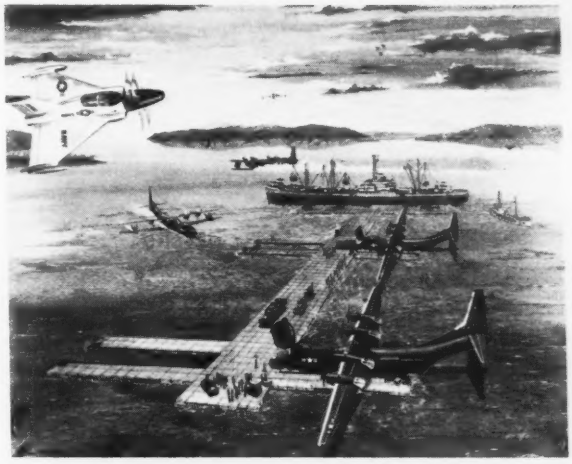


FIG. 18. A proposal for a mobile transfer point for loading assault seaplanes directly from ships.

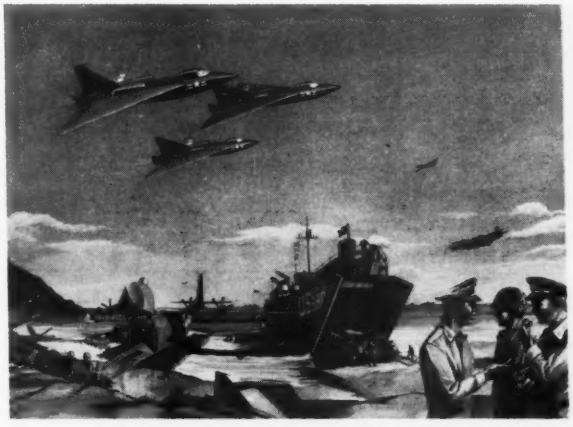


FIG. 19. A typical scene depicting beachhead support with bow-loading logistic seaplanes.

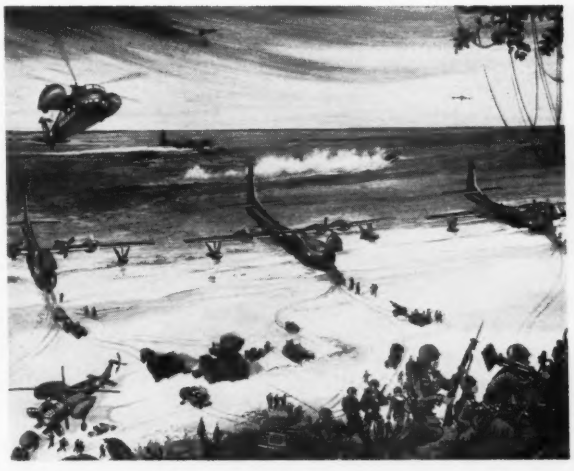


FIG. 20. An artist's concept of a commando-type raid on an unprepared beachhead utilizing logistic seaplanes with water-based fighter support.

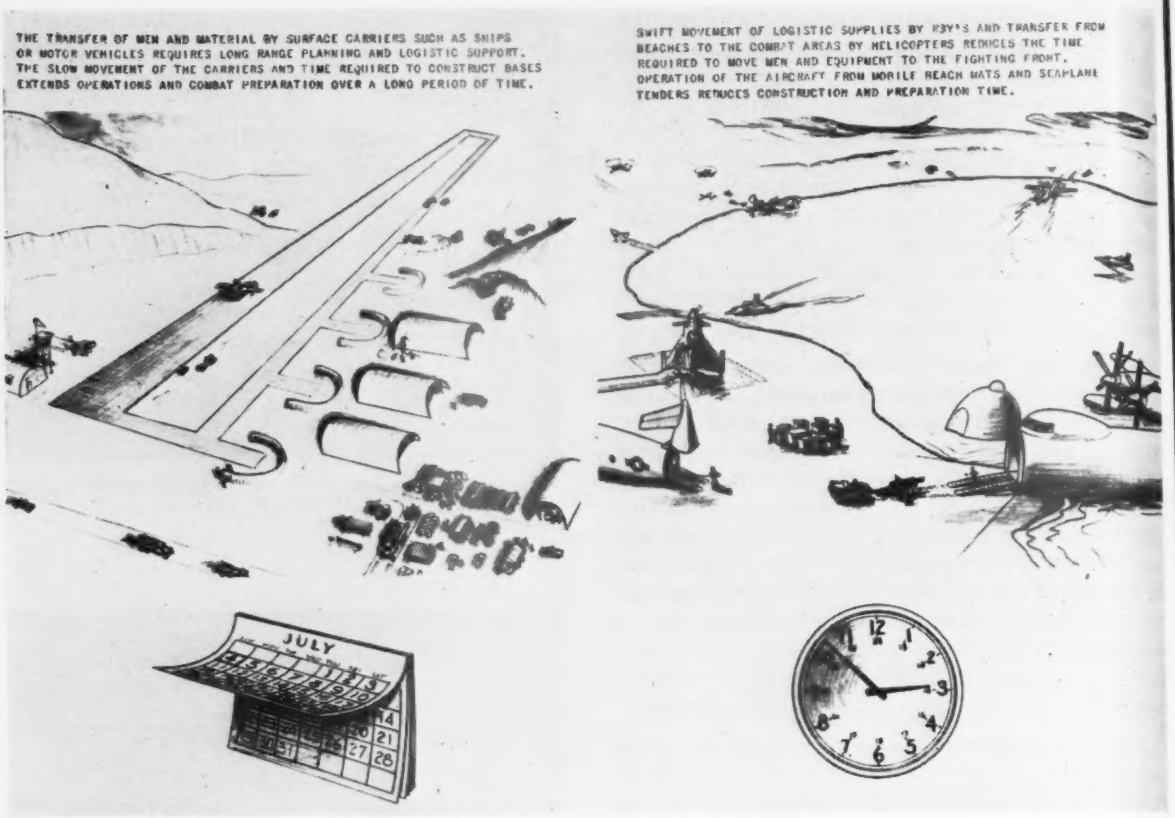

THE TRANSFER OF MEN AND MATERIAL BY SURFACE CARRIERS SUCH AS SHIPS OR MOTOR VEHICLES REQUIRES LONG RANGE PLANNING AND LOGISTIC SUPPORT. THE SLOW MOVEMENT OF THE CARRIERS AND TIME REQUIRED TO CONSTRUCT BASES EXTENDS OPERATIONS AND COMBAT PREPARATION OVER A LONG PERIOD OF TIME.
SWIFT MOVEMENT OF LOGISTIC SUPPLIES BY R3Y'S AND TRANSFER FROM BEACHES TO THE COMBAT AREAS BY HELICOPTERS REDUCES THE TIME REQUIRED TO MOVE MEN AND EQUIPMENT TO THE FIGHTING FRONT. OPERATION OF THE AIRCRAFT FROM MOBILE BEACH MATS AND SEAPLANE TENDERS REDUCES CONSTRUCTION AND PREPARATION TIME.
JULY

FIG. 21. Time of preparation, hours vs. days.

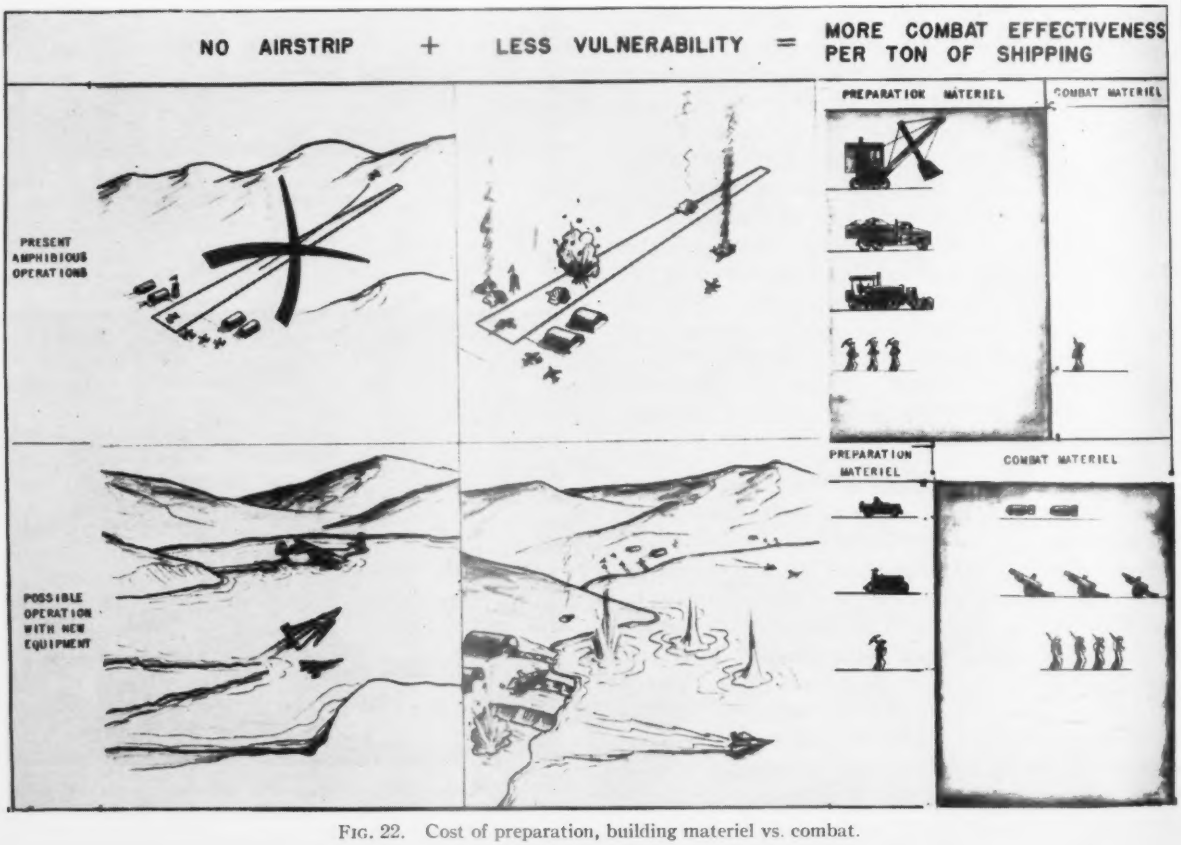

NO AIRSTRIP + LESS VULNERABILITY = MORE COMBAT EFFECTIVENESS PER TON OF SHIPPING
PREPARATION MATERIEL
COMBAT MATERIEL
PRESENT AMPHIBIOUS OPERATIONS
POSSIBLE OPERATION WITH NEW EQUIPMENT
PREPARATION MATERIEL
COMBAT MATERIEL

FIG. 22. Cost of preparation, building materiel vs. combat.

can readily be seen that logistic support of an advance striking force appears feasible with this unique aircraft.

The retractable loading ramps and spacious interior of the R3Y-2 Bowloader are further illustrated in Fig. 11. Of particular interest is the large cutout in the bow door which, in the raised position, provides the pilot with an unobstructed view of the beachmaster and the loading or off-loading operations. The large bow door is the forward pressure bulkhead and is designed to withstand the 7.5 lbs. per sq.in. differential pressure that allows an 8,000-ft. cabin altitude to be maintained at a cruising altitude of 35,000 ft. Fig. 12 is an aerial view of the Bowloader off-loading a howitzer and troops on an actual strip of unprepared beach in lower San Diego Bay. In an operation of this sort a stern anchor is deployed as the beach is approached to guard against broaching due to wind, tides, or surf.

To enhance the versatility of the R3Y-2 type of logistic transport, tanker provisions are being incorporated for the aerial refueling of fighters. Fig. 13 shows a division of four fighters flying in the positions required to contact the four refueling drogues that will be standard equipment in this configuration. The R3Y tanker is capable of refueling two such divisions (or eight fighters) during the tanker mission. In support of amphibious operations with water-based fighters, this operation could be accomplished either in the air or afloat.

F2Y Sea Dart

Having the logistic-support requirement well in hand with the R3Y-2 Bowloader, the main interest was next directed to the attainment of a high-speed, water-based fighter capable of providing the punch for a forward area striking force. It has been discussed previously how this development progressed through the transonic Skate program into the supersonic delta-wing configuration utilizing the NACA-developed hydroski. After many months of research in the NACA and Stevens Institute of Technology towing tanks, as well as free-body, jet-propelled model tests at Convair, the final go-ahead for the Sea Dart configuration was given in May, 1950.

With the start of actual construction of a supersonic seaplane fighter, the research studies were intensified with a series of larger and more detailed jet-propelled models such as the one shown in Fig. 14. These models were radio controlled and incorporated such features as scale oleo struts, remote ski position control, and other refinements. The largest model of this series was $^1/_6$ full scale, incorporating two 30-lb. thrust jet engines and eight channels of radio control.

The Sea Dart went into the water for the first time in December, 1952, and made its first flight in January, 1953. Fig. 15 (the headpiece, page 48) shows this aircraft planing at approximately 90 knots during a typical take-off run. The significant features of this unique water-based fighter are:

(1) Incorporation of integral beaching and taxi wheels which permit launching and beaching without the necessity for a beaching crew, buoys, or lines. These wheels incorporate brakes that in effect make the Sea Dart a typical landplane for all such functions as maintenance, re-arming, refueling, and stand-by readiness—utilizing the water only to eliminate the requirement for the long, costly concrete runway.

(2) The capability for very low planing speeds on water. Upon firing the afterburners for take-off the skis unport, and the aircraft is planing in less than its own length and at a speed of only 10 knots. This eliminates the large bursts of heavy spray which accompany the unporting phenomenon when it occurs at the customary higher speeds.

(3) Through the incorporation of long-stroke oleos, the Sea Dart, in spite of being a small fighter, has exceptional rough water capability.

(4) By lowering the wing until the trailing edge actually touches the water, adequate transverse stability is attained without recourse to high drag wing-tip floats. This can be accomplished because of the fact that supersonic requirements automatically provide the watertightness and strength necessary in the wing for this operation.

With the successful development of this design, the accomplishment of a forward area striking force, in being, advanced another significant step forward, incorporating an effective supersonic aircraft into the system.

FY VTO Pogo Stick

Since the basic concept calls for a forward area striking force that is not dependent upon advance preparation of concrete runways, there is no inherent requirement that the component aircraft must be water-based if some other basing method can accomplish the same overall purpose. This fact has been overlooked in the past, on many occasions, because of the erroneous assumption that water runways provided the only natural substitute for concrete runways. By keeping the broader point of view continually in mind, Convair did not restrict itself to hydrodynamic studies alone, even though this approach is the most direct and certainly the only feasible solution for the heavy logistic support component of the system. However, when

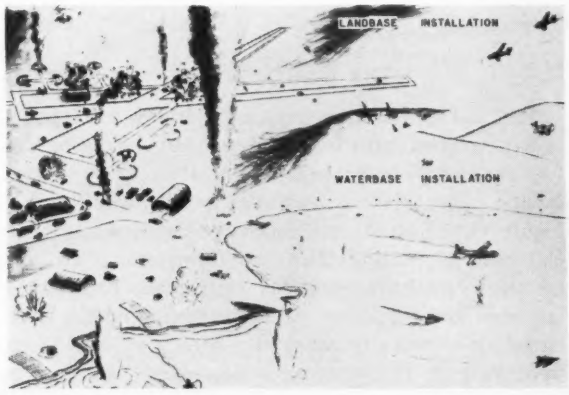


FIG. 23. High mobility and low attrition for water-based installations.

it became technically possible to develop a practical vertical take-off and landing tactical aircraft, it was immediately integrated into the system for those missions where it was best suited.

By the very nature of the status of power-plant development it was obvious that turbojet VTO's would not be feasible for many years to come; therefore, suitable missions for a vertical take-off turboprop aircraft were studied. In the fields of tactical close-air ground-support and convoy fighter protection from small ships, the vertical rising turboprop fighter appeared attractive. In March, 1951, the Navy Department contracted for the XFY-1 VTO turboprop fighter shown in Fig. 16. This aircraft made its first successful free-flight hovering flights in August, 1954, and successfully accomplished transition from vertical take-off to level flight and back to the vertical for landing in November, 1954.

As noted in Fig. 16, the XFY-1 is a cruciform delta-wing configuration and sits at rest in the vertical position on a landing gear contained at the extremities of the wing tips and vertical tail surfaces. This configuration has many inherent advantages for a successful vertical take-off aircraft:

(1) The delta wing has an inherent aerodynamic characteristic that allows it to operate smoothly through a very great angle of attack range without stalling.

(2) The delta wing, because of its geometric shape, results in an extremely low center of gravity when sitting in the vertical position. This is important from a toppling or upsetting standpoint.

(3) Coupled with (2) above, the broad tread of landing gear provides a large footprint area that gives the XFY-1 excellent stability while taking off or landing in the vertical position. This is particularly critical when operating in a strong wind and is accomplished in this design by virtue of the tailless delta cruciform design.

With an aircraft having the versatility and low-level striking power of the VTO integrated into the system as an active component, the necessary ingredients for an effective mobile force capable of dispersion and rapid employment in forward areas are now complete. The next section of this paper will discuss briefly how these components might be employed as an integrated tactical team.

The Weapon System

The fast carrier task force of World War II was a potent weapon, greatly feared and largely responsible for the complete subjugation of the enemy in the Pacific. Yet this force had to carry all of its aircraft in highly complicated and expensive carriers and with elaborate supporting ships and formations. To hold advances costly amphibious operations had to be launched and supported in order to bring up the land-based air superiority required. After the beachheads were secured, many weeks were required to prepare these strips for operation, during which period air support was largely furnished by the immobilized and vulnerable task force. If the concept originally assumed is possible, it becomes feasible to supplement this great, inherently mobile striking force with its own water-borne support and holding force. Carried in great numbers on cheap, simple ship tenders of all classes or ferried in from unprepared staging bases, this force is ready to saturate the air from unprepared strips almost immediately after the beachhead is secured. The elaborate and highly specialized carrier task force is freed almost immediately for new hit-and-run assaults for which it is ideally suited.

Such a possible situation is represented in the artist's sketch in Fig. 17. While no effort has been made accurately to portray a strategically sound deployment, the sketch does indicate types of equipment involved and how they might be used. The number of aircraft that can be assembled in any given area or operation need no longer be a function of multiplying the number of carriers by their complement of aircraft. The saturation of aircraft for holding, support, interdiction, and air superiority can be assembled rapidly, in any required number, from the ordinary logistics support ships in the fleet. Because of the decentralization of this force, defense from atomic attack by dispersion of men and equipment is enhanced. The fact that the beachhead itself could be dispersed over many miles of coastline and not concentrated on a heavily defended airstrip location diminishes vulnerability and increases the element of surprise to a great extent. As a matter of fact, water bases could be set up on islands or coastlines completely unable to support an airstrip. The enemy, having knowledge of this fact, would be forced to spread his defenses very thin, thus eliminating for the most part the costly amphibious frontal assaults against the heavily defended strategic beaches of the last war.

Aside from the obvious elements of improved strategy, other possibilities of great importance come immediately to one's attention. A great amount of offensive and defensive air action takes place over the water. Aircraft equipped with wheels for these operations are performing over an element for which they are inherently unsuited. Any minor damage in the air, a faulty catapult shot, or even a shortage of fuel results in a ditching where the aircraft, and frequently the crew, are irretrievably lost. As occurred in World War II, if the floating airstrip itself is lost or seriously damaged its entire complement of aircraft is lost, usually with heavy loss of life if in Arctic or infested waters. It would be an economic and morale consideration of great significance to have aircraft naturally adapted to the terrain involved—where, upon suffering minor failure, the crew rides safe and dry, and the expensive and vital aircraft is salvageable.

All-weather operation is a strategic requirement of utmost importance as the advantage will always be with the force that can fully utilize zero-zero conditions. Such operation is greatly enhanced by the use of water-based aircraft because of the wide tolerance usually available for the point of touch-down and heading during landing. Precise positioning of a jet aircraft on a

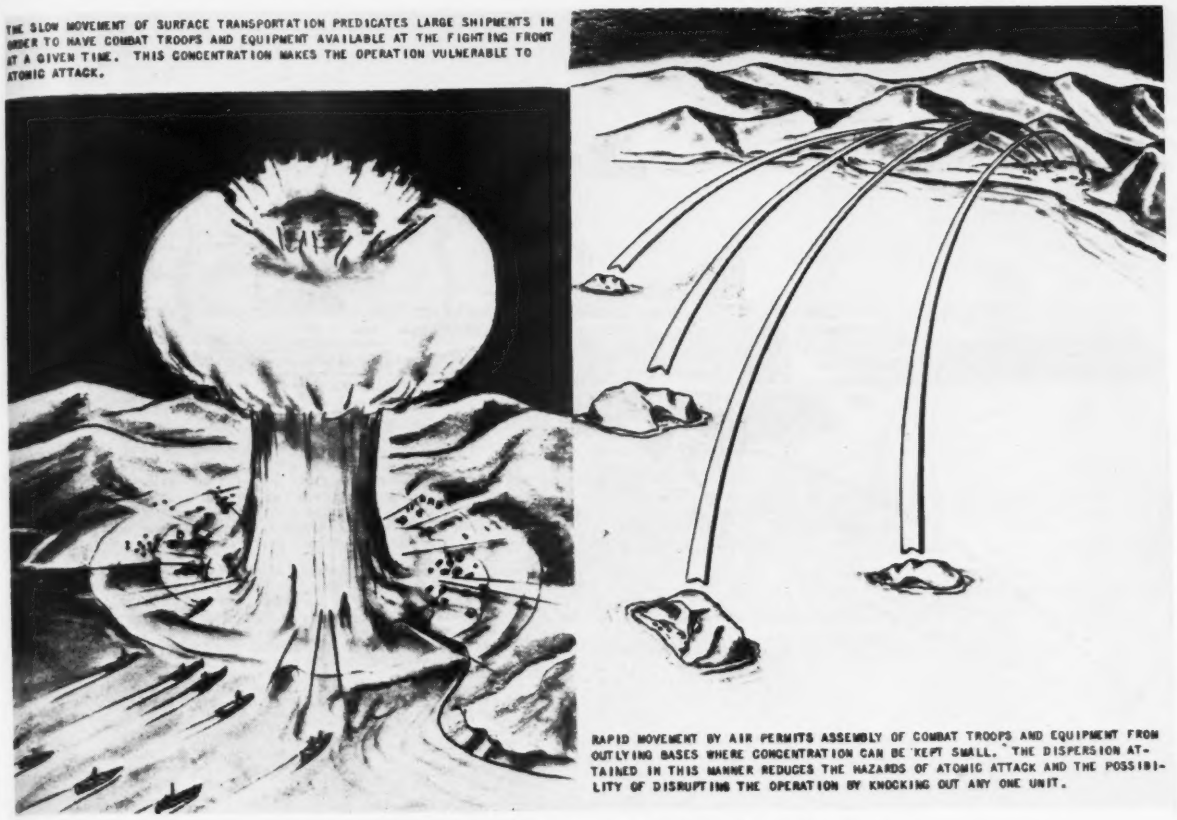

THE SLOW MOVEMENT OF SURFACE TRANSPORTATION PREDICATES LARGE SHIPMENTS IN ORDER TO HAVE COMBAT TROOPS AND EQUIPMENT AVAILABLE AT THE FIGHTING FRONT AT A GIVEN TIME. THIS CONCENTRATION MAKES THE OPERATION VULNERABLE TO ATOMIC ATTACK.
RAPID MOVEMENT BY AIR PERMITS ASSEMBLY OF COMBAT TROOPS AND EQUIPMENT FROM OUTLYING BASES WHERE CONCENTRATION CAN BE KEPT SMALL. THE DISPERSION ATTAINED IN THIS MANNER REDUCES THE HAZARDS OF ATOMIC ATTACK AND THE POSSIBILITY OF DISRUPTING THE OPERATION BY KNOCKING OUT ANY ONE UNIT.

FIG. 24. Effective dispersion of force in the face of a nuclear threat.

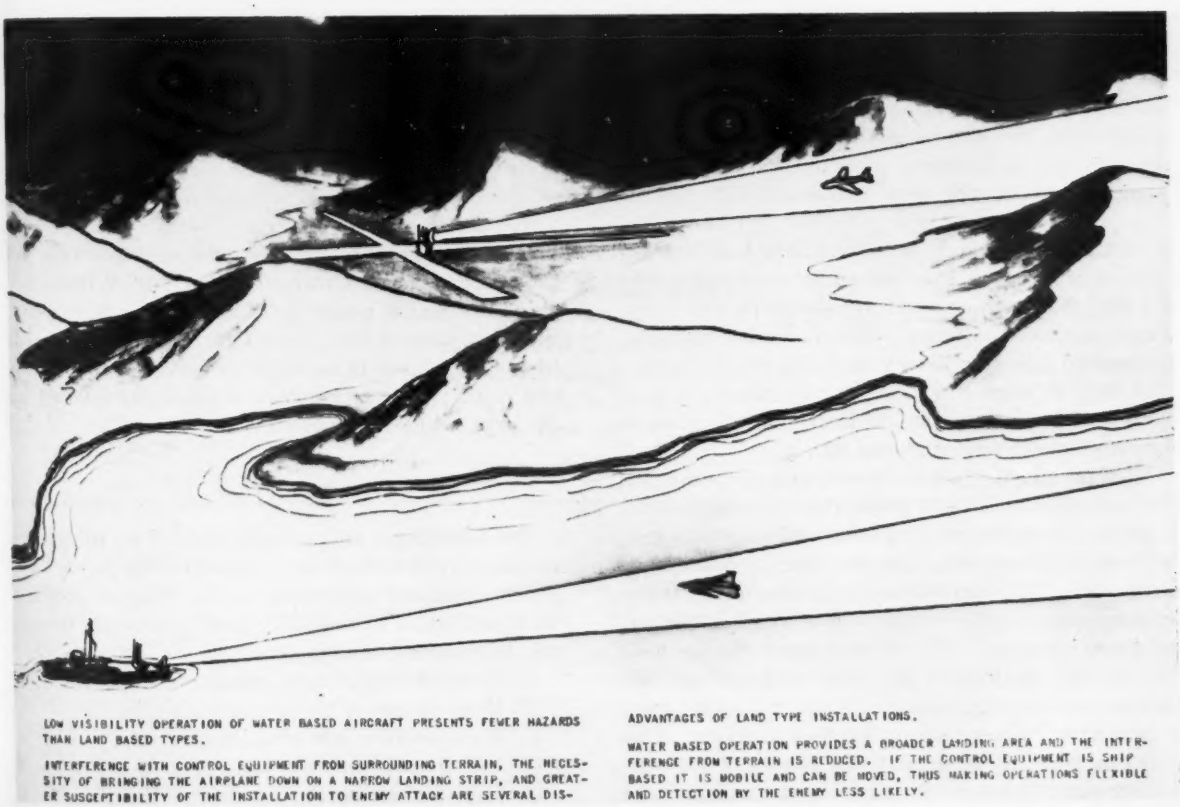

LOW VISIBILITY OPERATION OF WATER BASED AIRCRAFT PRESENTS FEWER HAZARDS THAN LAND BASED TYPES.
INTERFERENCE WITH CONTROL EQUIPMENT FROM SURROUNDING TERRAIN, THE NECESSITY OF BRINGING THE AIRPLANE DOWN ON A NARROW LANDING STRIP, AND GREATER SUSCEPTIBILITY OF THE INSTALLATION TO ENEMY ATTACK ARE SEVERAL DISADVANTAGES OF LAND TYPE INSTALLATIONS.
WATER BASED OPERATION PROVIDES A BROADER LANDING AREA AND THE INTERFERENCE FROM TERRAIN IS REDUCED. IF THE CONTROL EQUIPMENT IS SHIP BASED IT IS MOBILE AND CAN BE MOVED, THUS MAKING OPERATIONS FLEXIBLE AND DETECTION BY THE ENEMY LESS LIKELY.

FIG. 25. Improved all-weather capability for water-based aircraft.

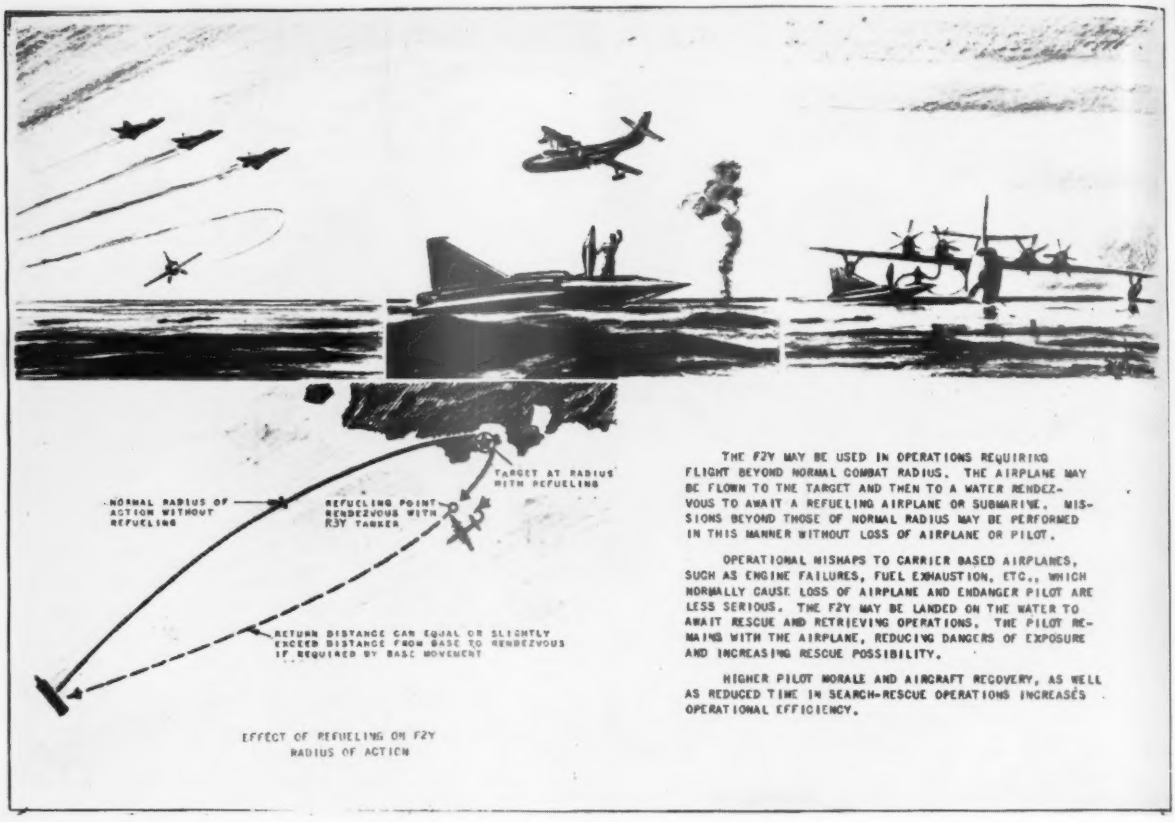

NORMAL RADIUS OF ACTION WITHOUT REFUELING
REFUELING POINT RENDEZVOUS WITH R3Y TANKER
TARGET AT RADIUS WITH REFUELING
RETURN DISTANCE CAN EQUAL OR SLIGHTLY EXCEED DISTANCE FROM BASE TO RENDEZVOUS IF REQUIRED BY BASE MOVEMENT
EFFECT OF REFUELING ON F2Y RADIUS OF ACTION
THE F2Y MAY BE USED IN OPERATIONS REQUIRING FLIGHT BEYOND NORMAL COMBAT RADIUS. THE AIRPLANE MAY BE FLOWN TO THE TARGET AND THEN TO A WATER RENDEZVOUS TO AWAIT A REFUELING AIRPLANE OR SUBMARINE. MISSIONS BEYOND THOSE OF NORMAL RADIUS MAY BE PERFORMED IN THIS MANNER WITHOUT LOSS OF AIRPLANE OR PILOT.
OPERATIONAL MISHAPS TO CARRIER BASED AIRPLANES, SUCH AS ENGINE FAILURES, FUEL EXHAUSTION, ETC., WHICH NORMALLY CAUSE LOSS OF AIRPLANE AND ENDANGER PILOT ARE LESS SERIOUS. THE F2Y MAY BE LANDED ON THE WATER TO AWAIT RESCUE AND RETRIEVING OPERATIONS. THE PILOT REMAINS WITH THE AIRPLANE, REDUCING DANGERS OF EXPOSURE AND INCREASING RESCUE POSSIBILITY.
HIGHER PILOT MORALE AND AIRCRAFT RECOVERY, AS WELL AS REDUCED TIME IN SEARCH-RESCUE OPERATIONS INCREASES OPERATIONAL EFFICIENCY.

FIG. 26. Improved morale and safety with water-based aircraft.

runway, both laterally and along its length, is a maneuver requiring the most elaborate flying aids known to the aeronautical sciences. On the other hand, a simple corner radar reflector attached to a rubber life raft is sufficient for the water-based aircraft where errors in alignment can be measured safely in hundreds of yards. Even if no ground aids are available to the pilot he has an excellent chance of saving himself and his aircraft in an emergency in zero-zero conditions if he has any radar on board, for it is an unfortunate and well-known fact that the one thing radar will always pick up is sea-return and bodies of water. When all other radar discrimination fails completely, the pilot can still find a large body of water which he can rely upon to be relatively free of obstructions—at least infinitely more so than any random area of ground terrain.

All of the efforts to attain forward area air power that is independent of advance preparation of bases in order to attain the maximum of mobility and dispersion may be in vain if this system is tied to a slow, unwieldy logistics complex that requires huge pipe lines, many transfer points, and—again—vulnerable airstrips at the forward area terminus. The obvious answer for the military logistic requirement is a large transport aircraft that can off-load large tonnages of material at the point of demand without recourse to fixed installations. This points immediately to water-based aircraft of the bowloading assault type of configuration, particularly since extensive surveys by the Coast and Geodetic and Hydrographic offices indicate that natural coastal and inland waterways already exist in every area of interest in the world. Figs. 18 and 19 graphically portray how the bowloading logistic transports can pick up critical materiel and troops from transfer points well behind the action and deliver these items directly to the point of demand. A striking force such as described, by virtue of its ability to disperse and move fast, becomes highly attractive for use in small commando-type assault groups such as illustrated in Fig. 20. With such a capability against poorly defended beachheads it is possible that many of the larger efforts could be eliminated. Obviously the key to such operations lies in the flexible and rapid pipe line of logistic support represented by the large bowloading transport.

CONCLUSION

The advantages and potentialities of an integrated system of aircraft, such as discussed in this paper, have been summarized graphically in the series of sketches shown in Figs. 21 through 27. Briefly these advantages may be enumerated as follows:

(1) Reduced time of base preparation (Fig. 21).
(2) Reduced cost of base preparation (Fig. 22).
(3) High mobility, low attrition (Fig. 23).
(4) Effective dispersion of force (Fig. 24).
(5) Improved all-weather capability (Fig. 25).
(6) Improved morale and safety (Fig. 26).

(7) Reduced handling and stockpile requirements with increased mobility for logistic support (Fig. 27).

The full employment of such a system, the basic components of which exist today, will provide the national defense with a forward area striking force that fully meets the premise of the basic concept—"Bases Unlimited."

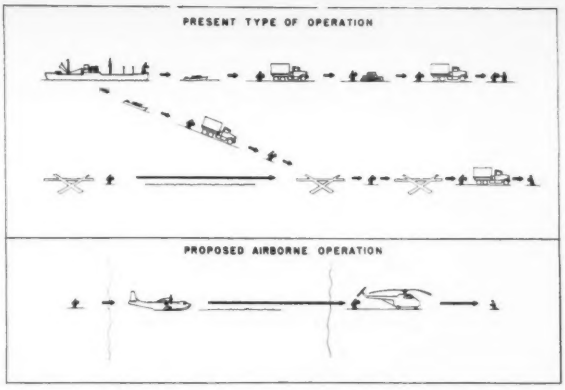


FIG. 27. Improved logistic support.

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The Procurability Program of the Air Force

How consideration of production potential in the earliest design stages may minimize subsequent problems of tooling, special machinery, labor skills, and material availability.

Otto H. Malz*
Wright Air Development Center

Introduction

It was stated recently by the Hon. Harold E. Talbott, Secretary of the Air Force, that the performance of our Air Force materiel is superior and that what we need now is quantity. This, of course, does not mean that we will remain static with respect to improvements in quality but that we should take action to ensure that we have superior quality and the required quantities when we need them.

The procurability program of the Air Force has been designed to meet the situation. Its objectives are reduction of the time and cost which are currently required to obtain operational quantities of Air Force materiel. It is recognized that the subject I am about to present is one that is fraught with areas of divergent opinion. The thoughts presented here represent many of the considerations given to the problem by research and design elements of the Air Force. They have been discussed with production and methods elements of Air Materiel Command, which is also responsible for procurability, producibility, and other logistic aspects of Air Force materiel. These elements are generally in agreement with the objectives about to be outlined. It is anticipated that, before the ideas here discussed have reached full accord with the gentlemen of the aeronautical industry and the Air Force, many reconciliations of detail and implementation methodology will need resolution.

This paper will explain what the term "procurability" actually means, and what makes it different from the better known term "producibility." It will then explain the nature of the procurability program and its compatibility with other design criteria, will review related efforts in foreign countries, and finally will describe the manner in which the Air Force intends to implement the program. Recommendations on action to be taken to achieve procurability conclude the paper.

Procurability Versus Producibility

The question appears justified whether the term producibility does not cover exactly what the Air Force desires to accomplish under the term procurability. The reply to this question is negative for the following reasons:

An article is called producible if it can be manufactured rapidly and economically in large quantities once the required tools, equipment, and skills have become available. The necessary tools, facilities, and equipment may be extremely expensive, but they will pay their own way because of the large quantity of articles to be produced. This permits the development of new production techniques and machinery and the training of necessary skills. Consequently, with the necessary effort in time, cost, and ingenuity, practically any article can eventually be made producible.

It is in the manner of spending this effort in time, cost, and ingenuity that procurability differs from producibility. The requirements of the national defense do not allow as much time for designing, testing, and production redesigning as is available for commercial articles. Everybody agrees that the producibility concept was brought to a remarkably high degree of perfection in private industry. However, the automotive industry experimented more than 10 years with automatic transmissions before they were released to production. On the other hand, we know of many cases in which Air Force materiel, because of the time pressure, had to be released to production immediately upon satisfactory demonstration of the so-called "breadboard model," with delivery schedules for production quantities so tight that there was just no time for the production redesign that is common practice for commercial articles. Of course, the designer of commercial products does not neglect the problem and requirements of subsequent mass production, but his effort is limited to very general considerations because there is sufficient time left after the completion of the necessary tests to make the article producible through production redesign. This time is not available to the designer of Air Force materiel. For this reason, the requirements resulting from the production of a still unknown quantity must be integrated into the preliminary design to an extent that is not required and not even justifiable in private business. The total effort in time, cost, and ingenuity required to make a commercial article producible must be advanced into the preliminary design phase of Air Force materiel in order to make it procurable. Air Force materiel cannot wait until the necessary production facilities and skills are available. Therefore, the design must make the maximum possible use of facilities and skills which are available at the time the green light is given to production. The design

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* Directorate of Laboratories.

must reduce to a minimum the requirement for new facilities, machinery, and techniques. The effect on national resources must be given more attention than is required for commercial articles. In those cases in which the use of new techniques, materials, and tools is mandatory for the realization of functional superiority, the procurability concept envisions concurrent development of these factors.

Producibility demonstrates a capability, but procurability is a design quality that integrates the nation's capacity to produce. A procurable article is inherently producible, but a producible design is not necessarily procurable. For all the reasons stated above, the Air Force has coined the new term "procurability."

Areas Requiring Procurability Effort

The procurability concept seems to be in serious conflict with other design criteria such as performance. First of all, it must be recognized that the procurability program does not establish an entirely new and revolutionary design concept. On the contrary, procurability, although not so named, was a common design quality at the time when the aircraft business was highly competitive not only from the standpoint of flight performance but from the standpoints of delivery schedule, unit cost, and maintainability as well. Today, however, in our quest for performance, we may have postponed the consideration of production. This could be disastrous in the event of a national emergency because there is no hope that a future war would allow the same gradual production build-up that has been our good fortune during previous emergencies.

The procurability program does not change the responsibility of production personnel for efficient and timely production to meet Air Force requirements. The program emphasizes, however, that the ability of the production and procurement personnel to accomplish their mission is dependent, to a considerable degree, on the action taken during the design and development phase. If this is recognized, there can be no doubt that it is the responsibility of preliminary design personnel to integrate the production potential into the design during its earliest stages and to inform the production personnel of unavoidable new requirements as early as possible, if procurability is to be achieved.

It seems quite obvious that the procurability effort must eliminate, or at least reduce, those factors known to be production bottlenecks. The tooling problem seems to be one of the most serious bottlenecks. This shows up in practically all progress reports furnished to the Air Force by prime contractors. Here are a few samples from progress reports: "Every effort has been expended to recruit skilled tool designers and toolmakers from all parts of the country"; "The subcontractor has encountered serious tooling problems"; "The difficulty in obtaining adequate tool- and diemakers and jig-erection workers has aggravated the tooling situation." These conditions have occurred in spite of the obvious effort to develop the necessary tooling concurrently with the design. Therefore, it appears only logical to reduce the tooling requirements. This can be done two ways—namely, by designing away from tooling requirements or by facilitating the toolmaking itself. An example of the first way is given in Fig. 1, which shows the original and the modified configuration of an aircraft windshield and canopy. The original design presented problems of installation, replacement, and accessibility. The change not only eliminated all these difficulties but even facilitated the tooling problems by employing a flat plane of attachment in lieu of the original curved one and by eliminating no less than 80 per cent of the attachments. The concurrent change in canopy shape and material reduced the cost of the canopy by 70 per cent. Performance of the aircraft was not affected by these changes. An example of the second way to reduce the tooling requirement—namely, by facilitating the toolmaking—is presented in the latest diemaking techniques. It is generally known that forging dies have been a serious tooling problem for many years because of the lack of diemakers and the man-hours required per die. These problems will be greatly alleviated—for example, with the introduction of cast dies, die inserts, and so forth on which the Air Materiel Command is currently working. The first example, which is shown in Fig. 1, is representative of the designer's contribution to procurability, whereas the improved diemaking techniques represent the production expert's contribution. The combination of the two efforts, effected at the time of preliminary design, is one of the biggest possible steps toward the achievement of procurability.

Let us consider another production bottleneck—the special machinery required. More than a decade ago, the machining man-hours amounted to approximately 25 per cent of the total direct manufacturing labor. This percentage has gone up recently to at least 40 per cent. Checking again into the progress reports, we find: "Although the total machining capacity

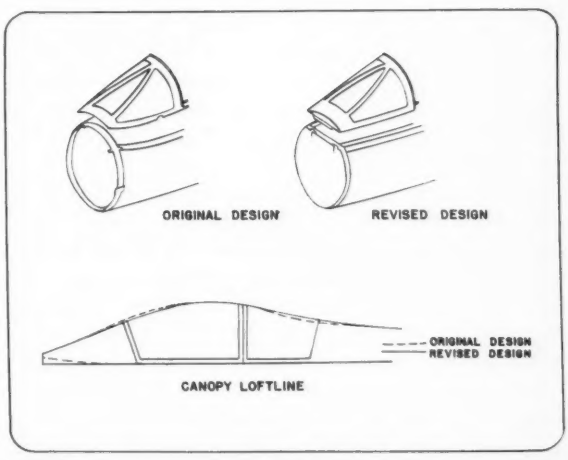

Fig. 1.

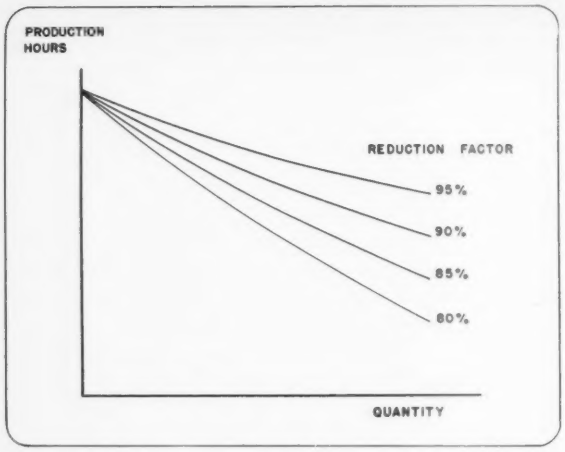

FIG. 2.

of all machine shops, including the Experimental Department, is being utilized to the fullest possible extent, scheduled production requirements will not be met"; or "Production schedules cannot be met since the required additional machine tools cannot be obtained from suppliers on schedule." A lead time of 3 years has been specified for some of the special machine tools required. If we commit our production firmly to such items, we would have to maintain a "preventive stockpile" of those items in order to be able to meet a national emergency. Of course, this could be done if we disregard the cost involved, but nobody knows whether these items will not be considered obsolete at the time the emergency occurs. Naturally, it could be decided that all future production must be based on this stockpiled machinery. If this is feasible, it would only be wise to make this decision right now and to settle for the very same production equipment and facilities which are available right now. The procurability concept does not establish such extreme requirements. It merely requires the design personnel to minimize the need for new or additional production capacity by maximum utilization of the available capacity, and it requires the production personnel to establish or expand that special production capacity considered mandatory. The forging capacity is a good example. During World War II, United States aircraft did not employ too many forgings. For example, the P-47 aircraft used only 500 lbs. rough forgings. Today the F-84 aircraft—a similar type of aircraft produced by the same manufacturer—uses more than 6,000 lbs. rough forgings. A few years ago this posed an extremely serious problem, and had it been necessary to build up our force in a hurry we would have had serious delays. Actually, the Air Materiel Command recognized the problem and initiated a large program to increase the forging capacity not only for small forgings but for larger ones also. This, together with the new diemaking techniques mentioned earlier, should eliminate the previous production problem. The employment of forgings today then could be considered procurable designing. As time goes on, however, it must be re-evaluated for each new design to ensure it is still a procurable design.

A similar consideration applies to the special production skills required. As mentioned before, the percentage of machine labor has grown during the last decade. We should not neglect to consider what this means to the production learning curve shown in Fig. 2 which has been developed in the aircraft industry during World War II and is known from publications—e.g., *Harvard Business Review*, January–February, 1954. This learning curve is based on the observation that any time the production quantities are doubled, the direct labor man-hour requirement is reduced by a constant factor. This reduction factor is a function of the percentage of machining labor. For 100 per cent machining operations, the learning curve approaches a constant value after all the machine tools have been set and adjusted appropriately. The combination of machine labor and manual labor results in learning curves that have smaller labor reduction for the higher percentage of machining. A decade ago the average reduction factor for the whole aircraft industry was about 80 per cent. If we compare the hypothetical case of two articles designed to the same specification—one of them manufactured with a high percentage of mechanized operations, the other one manufactured with a high percentage of manual operations—we find a situation similar to the one shown in Fig. 3. It is clear that the article manufactured by highly mechanized methods starts out with a reduced requirement of production hours. However, because of the difference in slope of the two learning curves involved, the two curves intersect at Point A. The exact location of this point is determined by the difference in the initial production hours and by the difference in slope of the two curves. If the difference in the initial production hours is very large, Point A will be located way out to the right of the chart, corresponding to very large quantities, and the employment of mechanized methods is well justified. However, if the intersection would occur as shown in Fig. 3, the area ABC represents savings in production

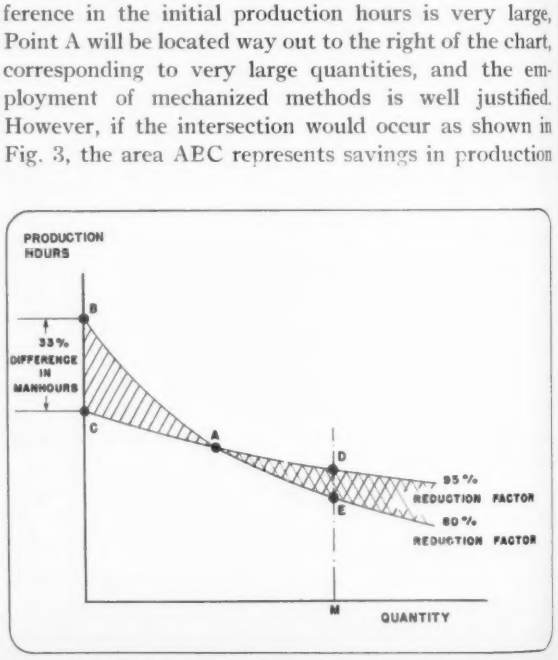

FIG. 3.

hours by employing mechanized methods, whereas beyond Point A the same methods would be less economical. For one particular quantity M the gains ABC are equal to the losses ADE. Actually, we may have spent considerable money and time to obtain the special machinery required for the increased mechanization. This would be adverse to the procurability concept, particularly if the skills required for the less mechanized production are readily available, and even would allow rapid production expansion in the event of an emergency. Mechanization as a modern trend in production has its definite merits, which this paper does not attempt to minimize. The hypothetical case shown in Fig. 3 indicates that their employment has to be carefully analyzed for every case before a design is committed to any one production method.

Another area requiring procurability effort relates to materials. It has happened that production was committed to new equipment which did not become available on schedule because of the nonavailability of materials specified for the production article. It is quite obvious that a design specifying large amounts of critical materials is less procurable than a competitive design that eliminates such need. There are other materials that are not critical but in short supply. They should never be subjected to manufacturing processes that have poor material utilization factors as expressed by the ratio of raw weight to the weight of the finished article, particularly if there is no way known to recover the material from chips. In this connection the titanium situation deserves a few words. Several years ago, titanium was considered as the new "glamour material." As a result, the requirement rose rapidly high above the capacity as shown in Point A of Fig. 4. The Air Force, anticipating future demands, began to expand the capacity. The requirement, however, dropped sharply. This was due not only to the limited availability but also to a certain disappointment resulting from the lack of uniform quality of the material and to the unknowns in titanium metallurgy which had been detected in the meantime. At Point B of Fig. 4 the demand began to drop below the supply,

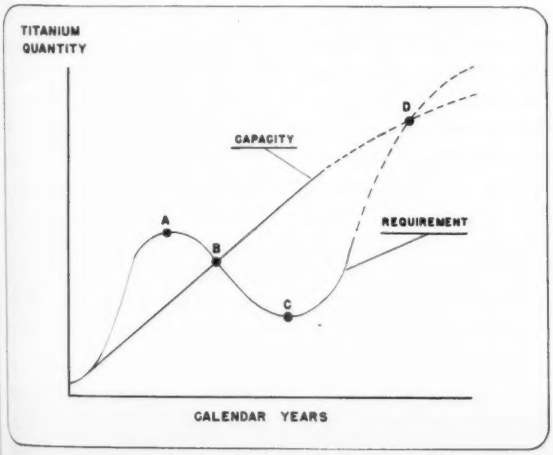

FIG. 4.

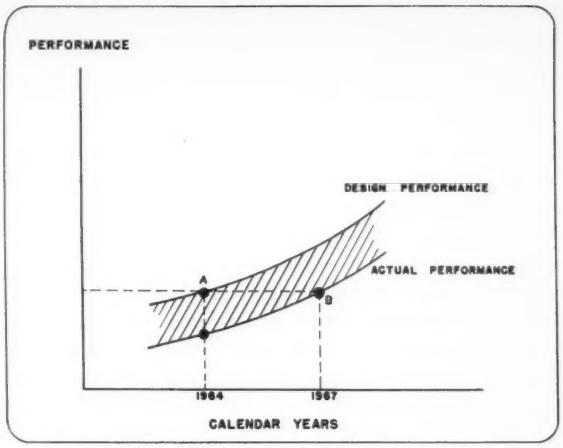

FIG. 5.

but the Air Force continued the expansion of the titanium capacity, knowing that the demand would rise again once the current problems with titanium have been solved. Since experience with titanium can grow only with its use, the Air Force encourages the employment of titanium structures despite the current high cost of the material. This seems to be in contradiction to the procurability program. However, it must not be forgotten that the procurability program is a long-range program. It is anticipated that in the not too distant future, shown at Point C in Fig. 4, the requirements will go up again. The material cost will eventually come down, and titanium structures will become procurable. It will be the concern of the Air Force to prevent the demand from rising again above the supply, as indicated beyond Point D in Fig. 4.

COMPATIBILITY OF PROCURABILITY WITH OTHER DESIGN CRITERIA

The most common objection raised against procurability is its alleged incompatibility with performance requirements. It must not be forgotten that performance requirements are established with respect to some operational date. Let us assume that the design of a superperformance aircraft would be initiated today with the objective to be operational in 1964. If the design follows the current practice, delays in tooling and production will be unavoidable, and the aircraft might finally become available in 1967. However, if the design complied with the procurability concept, operational quantities could actually be available in 1964 as planned. Procurability then enables us to have aircraft with the desired performance when we need them. Without procurability this performance is not available for 3 years hence. This shows that the procurability concept is entirely compatible with the performance requirements. It even opens the question whether procurable designing would not permit a compromise to performance commensurate with the gain in availability. In Fig. 5 the design performance is plotted against time in years. Our superperformance

aircraft designed to be operational in 1964 would appear in Point A of the design performance curve. Because of the slippages discussed before, the aircraft following the current practice would become available in 1967 with the identical design performance. Point B, therefore, marks the actual performance, and the curve for actual performance would be approximately parallel to the design performance curve. This shows that as long as we stay between Points A and B for the design under consideration or within the shaded area in general, we could afford to trade performance for availability. Actually, the procurability program is aimed at Point A or at the design performance curve. After procurability is integrated into all Air Force materiel, the curve for actual performance will coincide with the design performance curve. The trading of performance for availability is, therefore, only feasible during the transition period.

The next common objection is that it will cost too much time and money to integrate the production requirements. It has already been stated before that the effort in time and money currently required will not be increased. Producibility studies, production implementation studies, product improvement contracts, and production refinement work are representative of this total effort, which, under the procurability concept, will merely be rescheduled, all of it being advanced into the design and development phase.

Another objection is that time and money spent on procurability may not be justified because we are not sure the item will be committed to production. Experience will show that the effort required to incorporate procurability into the preliminary design will diminish gradually with the growing experience and enthusiasm on the part of design personnel. Furthermore, the knowledge gained in applying the concept to designs that did not go into production will be valuable for subsequent designs. The effort will not be wasted. In matters affecting the nation's safety, we can afford to spend money, but we cannot afford to lose time. Needless to say, the Air Force will determine those cases where procurability will not be a consideration. These cases may not be limited to research or state-of-the-art work.

It has been stated that the procurability concept will kill the ingenuity of design personnel. To my mind just the opposite is true. It is a challenge to the designer's ingenuity to try to stay within the limitations imposed by available labor skills and production capacity and still achieve the same performance level that a competitive, nonprocurable design reaches only with a delay of several years. Furthermore, the procurability concept in no way limits the ingenuity of production experts to develop new techniques, equipment, and special capacities. It merely curbs the premature commitment of a design to innovations in all instances where the same performance could be achieved earlier and as economically by the employment of the available production capacity.

Review of Related Efforts

It was mentioned previously that the producibility concept has been brought to a remarkably high degree of perfection in private industry. Application of such effort to Air Force materiel will be made with the reservations resulting from the basic difference between the two concepts of procurability and producibility which have been explained before.

There have been several efforts in the aeronautical industry to penetrate into the area of procurability. The Air Force will support and consolidate all these individual efforts to the greatest possible extent.

The Air Force has so far initiated producibility studies, production implementation contracts, product improvement studies, and production refinement work. All of this, however, followed more or less the producibility concept. In other words, this work was started after completion of the design. Consequently, the results of such work were frequently not available early enough to realize the intended savings. This work is representative of the total effort that now, under the procurability concept, will have to be advanced into the design and development phase.

It also appears advisable to scan the activities of other nations, particularly of those confronted with shortages in natural resources, engineering talents, manpower, facilities, etc. Consider first the Soviet Union. All of the various sources that have evaluated Russian products agree that the Soviet motto for design and production seems to be "Nothing can be too simple and too raw if it meets the requirement of military effectiveness." The Russian designers have decided on methods of production which the United States aircraft industry is inclined to consider obsolete. It appears, however, that the Soviet performance level cannot be considered as equally obsolete. It appears that the Soviet aircraft industry has been forced to accept the domestic limitations in physical equipment and available skills.

The United Kingdom displays a distinct desire for procurable materiel. We have all read of recent British fighter aircraft that are reportedly designed for rapid and inexpensive production. We have also heard of the "midget" aircraft that are reduced in dimensions for the sole purpose of reducing the production requirements. Editorials in British magazines with headlines such as "More—More Quickly" show clearly the desire for procurability. Publicity has further been given to British production methods like—for example—the PETAL construction that allows the fabrication of complex curved surfaces from sheet material with no preforming required for the sheets. Further, the desire and need to achieve what we call procurability has been emphasized in many speeches given by top government officials.

It appears that the U.S. Air Force is not the leader in procurability matters. No reason can be seen, however, why American ingenuity should not be able

to take the lead in procurability just as it has done in so many other fields of technology.

Implementation of the Procurability Program

The Air Force does not expect private industry to be fully cognizant of all those aspects of the nation's production potential and the national economy which affect the procurability of Air Force materiel. Therefore, the Air Force will release general recommendations for procurable designing. These will include not only processes to stay clear of but also recommendations to use specified new and advanced techniques that have been worked out satisfactorily. Compliance with these recommendations during the design and development phase will be made a contractual requirement. Deviations from these recommendations will be permitted only if a satisfactory justification is submitted together with the design proposal. Prior to approval, the impact of the deviation on both performance and availability will be carefully analyzed by the Air Force. The general recommendations will be worked out on a selective and progressive basis.

It is contemplated that a procurability section will be added at a later date to the *Handbook of Instructions for the Aircraft Designer*, ARDC Manual 80-1. This section will contain all applicable design recommendations. It will have to be continuously adjusted to changes in the conditions affecting the procurability concept.

The Air Force is prepared to provide guidance and funding for the procurability program. The basic engineering work must, of course, be performed by industry. The Air Force will furthermore arrange for an efficient exchange of information and will promote separate procurability studies whenever they seem to be warranted or necessary.

The implementation of the procurability program will require close collaboration between preliminary design, tooling, and production departments. The preliminary design personnel will probably be the partner requiring the most education on procurability matters. It is well known that the three departments involved have never been working independently of each other, but the collaboration has to be made much closer, and production personnel must be informed early enough of design requirements. With procurability as the objective, the topic of all common discussions should be, "Can we produce it immediately in quantity?" in lieu of the current topic, "How can we make it producible?"

Multiple usage of parts, components, and subassemblies would improve the procurability of Air Force materiel appreciably. There are cases in which the anticipated production requirements could never be met with the available production capacity and labor skills without systematic standardization. In one of these cases, more than 20 different systems, using the same basic principle, are required for various weapon systems. The individual quantity requirements are relatively small. It is a necessity in this case to standardize all parts, components, and subassemblies which are common or can be made common to the 20 different systems. A pertinent procurability study is already under consideration, and more of them are to follow. Success can be achieved only by rigorous adherence to the Department of Defense standardization program.

It is recognized that fluctuations in the workload, as they were characteristic to the aircraft industry in the past, have a tendency to aggravate production problems such as shortages in special skills. The current trend of "stretching" the defense program over a longer period of time does in no way relax the requirement to achieve procurability. On the contrary, the requirement is even emphasized. Stabilized workload means stabilized labor forces, but stabilized at a level that is lower than the peaks reached under the previous concept with its fluctuations in workload. With stabilized workload and labor force, it becomes even more necessary than before to integrate procurability into the design.

Conclusions

In conclusion, the following recommendations are offered as the initial steps toward the implementation of the procurability program:

(a) Educate all personnel involved in design and production of Air Force materiel toward a thorough understanding of procurability.

(b) Review and re-evaluate the current concepts of designing, tooling, and processing for their respective compatibility with the procurability concept.

(c) Establish and maintain the closest possible collaboration between preliminary design, tooling, and production departments in order to eliminate the current delays in tooling and production.

(d) Separate innovations in methods and techniques from the development of Air Force materiel in all cases where the availability of operational quantities would be compromised by premature commitment to such innovations.

(e) Never consider a technique as obsolete which performs better in the event of an emergency than a more "progressive" technique.

(f) Never forget that procurability, even if achieved at the expense of money, is of greater importance to the nation's safety than producibility, which is achieved at the expense of time.

The Control of Turbojet Engines

A Discussion of Present Complexity and Methods of Simplification

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Introduction

The advent of the gas-turbine jet engine was hailed as an engineer's dream because of its simplicity. The simple turbojet engine has only one main rotating shaft as compared with the numerous reciprocating and rotating parts in a piston engine. This dream of simplicity has gradually been dispelled by the constant improvement and development which have increased the complexity of the control system even more than that of the engine. The present-day control system is required not only to control a more complex engine but to do so with greater accuracy in order to exploit fully the potential performance gains now available.

This paper shows how the complexity of a present-day turbojet control system is the direct result of improved engine performance and expanded flight limits. Several means of control simplification are suggested.

Evolution of a Typical Turbojet Engine Control System

For military aircraft there are three outstanding control requirements:

(1) Single power lever control is desired to relieve the combat pilot of as much engine responsibility as possible.

(2) A linear thrust to power lever relationship is required to aid the pilot in selecting the correct thrust, particularly when flying close formation.

(3) The control system must be capable of preventing engine damage or malfunction when the power lever is moved rapidly from one power setting to another.

The above requirements must be met throughout the entire operating range of the engine. In addition, there are numerous detail requirements such as maximum power lever torque limits, acceleration and deceleration time limits, maintenance of optimum engine operation for all power settings, automatic sequencing of component operation, etc.

Fig. 1 illustrates a typical present-day turbojet engine control system that will meet the above requirements. For a better understanding of this control system it is well to show how each component came into being.

All-Speed Governor

A single power lever is pictured with a quadrant divided into equal increments of thrust. This single power lever must control all thrust changes of the engine.

There are numerous variables that can be used to control thrust, but experience to date has shown that rotor r.p.m. is easy to obtain and control. Item 1 of Fig. 1 illustrates the r.p.m. versus power lever position required to maintain a linear thrust relationship. To accomplish this an all-speed governor must be furnished with rotor r.p.m. and power lever position as input variables. Fuel flow is the controlled output variable, and the control loop is closed through the engine because increased output fuel flow will increase r.p.m., and decreased output fuel flow will decrease r.p.m.

A simple droop-type flyweight governor must be compensated for different engine loads. The fuel valve is positioned directly by the flyweights, and a different r.p.m. exists for each fuel valve position. The engine load—and, hence, the fuel requirement for a given r.p.m.—is a function of engine inlet pressure and temperature. These variables are often used to reset a droop-type governor to prevent engine overspeed.

A null-type isochronous flyweight governor is frequently preferred over the droop-type to avoid the use of compensating mechanism. This type of governor positions the fuel valve with a flyweight-operated servo, thus maintaining a fixed flyweight position for all fuel flows.

Engine damage or malfunction must be prevented during rapid movement of the power lever, therefore more intelligence must be built into the all-speed governor to control acceleration and deceleration of the engine. Without this added intelligence, the all-speed governor would supply the engine with too much fuel during underspeed conditions and overheat the turbine, or stall the compressor, or both. Conversely, during overspeed conditions too little fuel would be supplied to the engine, and loss of combustion would result. Again there are several engine parameters that could be used to control acceleration. In the typical case illustrated as Item 2 of Fig. 1, referred fuel flow is scheduled versus referred r.p.m. Referred fuel flow and r.p.m. are the actual values corrected to standard day compressor inlet pressure and temperature. These referred quantities have the advantage of being nearly equal in magnitude to the corresponding actual values under standard conditions. Referred acceleration fuel flow plotted versus referred r.p.m. for various compressor inlet conditions is essentially a single line. This referred function is used as the control schedule. The schedule is maintained by supplying a hydromechanical computing mechanism with compressor inlet pressure and tempera-

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ture. Open-loop control results because changes in fuel flow do not change the compressor inlet pressure or temperature.

Afterburner Control

More thrust is frequently required for an airplane engine combination to improve the airplane performance. This added engine thrust must frequently be accomplished with no increase in engine diameter because the airplane is already designed. Added thrust can be supplied without changing the basic diameter by the addition of an afterburner. Afterburners are also practical in many transonic interceptor-type airplanes where additional thrust is required for short duration such as take-off, climb, or high-speed bursts. Afterburning permits a lighter installation capable of rapid climb and high flight speed. The afterburner fuel control illustrated as Item 3 in Fig. 1 schedules fuel flow as a linear function of compressor discharge pressure. This can be done because compressor discharge pressure is an approximate indication of mass airflow if the engine r.p.m. is at or near maximum. A near-optimum air/fuel ratio can thus be accomplished by scheduling fuel flow as a function of compressor discharge pressure.

A means of afterburner fuel ignition must also be supplied. A typical afterburner ignition system consists of firing a "hot streak" of burning fuel into the afterburner.

Greater afterburning efficiency is obtained if it is restricted to maximum or near-maximum r.p.m. operation of the basic engine. This restriction can be accomplished by obtaining an r.p.m. trigger signal from the added intelligence previously incorporated in the all-speed governor to prevent the afterburner fuel control from supplying fuel or the ignition "hot streak" to the afterburner until maximum engine r.p.m. has been reached. By preventing premature afterburner ignition, the r.p.m. trigger signal permits the power lever to be moved rapidly from any low power setting to the afterburning power setting without danger of compressor stall or turbine overtemperature.

Partial afterburning augmentation is provided as a function of power lever position. Complete modulation cannot be attained because reducing the afterburner fuel flow eventually results in an air/fuel ratio too lean to support afterburner combustion.

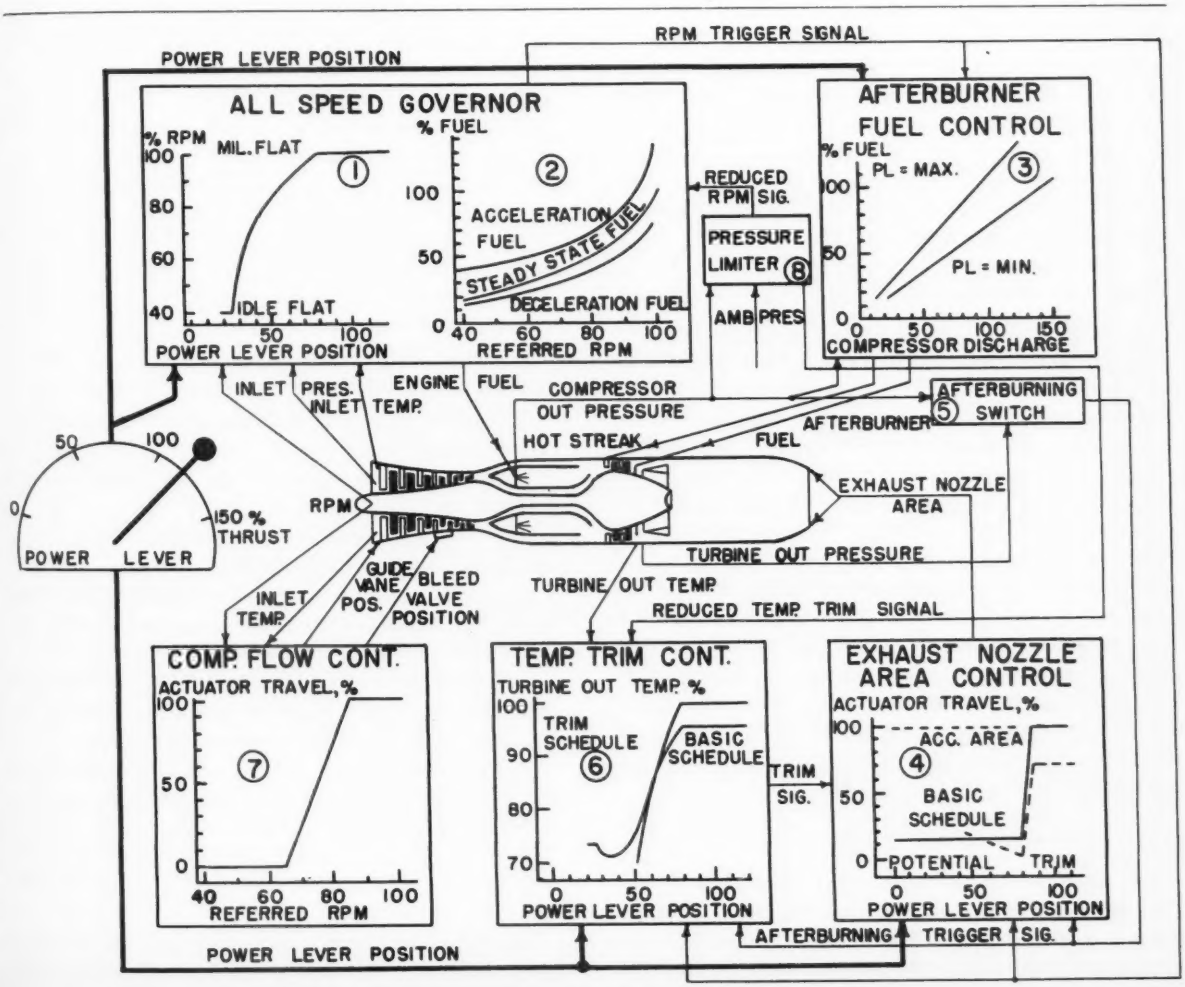

FIG. 1. Typical control system for a present-day turbojet engine.

Exhaust Nozzle Control

Maximum afterburning augmentation requires a greater exhaust nozzle area than maximum basic engine operation because essentially the same mass flow of gases must be handled at elevated temperatures. A two-position exhaust nozzle control—a large area for burning and a smaller area for nonburning—could be supplied, but full exploitation of the afterburner cannot be obtained without a modulating exhaust nozzle. Item 4 of Fig. 1 represents a modulating exhaust nozzle control. The basic two-position exhaust nozzle areas are represented by the solid line with a potential trim area superimposed.

Two trigger signals are also fed into the exhaust nozzle control. Faster engine acceleration is obtained with an open exhaust nozzle, and the r.p.m. trigger signal is used to lock the exhaust nozzle in the open position until an "on-speed" condition is reached. The afterburning trigger signal is used to keep the exhaust nozzle in the closed position until afterburner ignition is obtained, because for high-altitude operation better ignition is obtained with a closed nozzle. A thrust loss during the transition from nonburning to burning operation is also prevented.

Afterburning Switch

The afterburning switch, Item 5 of Fig. 1, uses the pressure ratio across the turbine to supply the exhaust nozzle control with an afterburning signal. Because the afterburner is ignited with the exhaust nozzle closed, the turbine pressure ratio is upset as soon as ignition occurs and the afterburning switch sends an opening signal to the exhaust nozzle control.

Temperature Trim Control

As previously mentioned, full utilization of afterburning augmentation requires a modulating exhaust nozzle. In the control system pictured in Fig. 1, the exhaust nozzle modulation signal is supplied by the temperature trim control, Item 6. The temperature trim control is an electronic computer that compares the actual turbine outlet temperature with a predetermined temperature schedule as a function of power lever position. If an error in temperature exists, the temperature trim control sends an appropriate trim signal to the exhaust nozzle control. Closing the exhaust nozzle increases turbine outlet temperature, and opening the exhaust nozzle decreases temperature. The same trigger signals sent to the exhaust nozzle control (r.p.m. and afterburning) are sent to the temperature trim control to render it inoperative while the basic schedule of the exhaust nozzle is being overridden.

Compressor Flow Control

The constant development of the basic turbojet engine to improve specific fuel consumption, specific weight, and thrust per frontal area has resulted in higher compression ratio compressors that require still another control. High compression ratio, single-spool compressors have serious stall difficulties in the low r.p.m. range. To alleviate this problem, movable inlet guide vanes and air bleed provisions have been incorporated in many present-day engines. The compressor flow control, Item 7 in Fig. 1, is added to the control system to control the angle of the compressor inlet guide vanes and to regulate a mid-section compressor bleed valve. This is done by scheduling the compressor inlet guide vane and bleed valve actuator position as a function of referred r.p.m. The compressor flow control is an independent open-loop control that uses rotor r.p.m. and compressor inlet temperature as input signals.

Pressure Limiter

Present and anticipated high flight speeds plus high pressure ratio compressors have increased the engine internal pressures to a degree where excessive engine weight would be required to prevent bursting of the engine. To prevent engine bursting and at the same time permit high flight speeds, a pressure limiter, Item 8 of Fig. 1, can be incorporated. The pressure limiter is a comparatively simple, closed-loop control that compares compressor discharge pressure with the engine ambient pressure. Engine r.p.m. and turbine outlet temperature are reduced by the pressure limiter if the difference between compressor discharge pressure and engine ambient pressure exceeds a predetermined value.

With the completion of the control system illustrated in Fig. 1, it can be clearly seen that the control of a modern turbojet engine is extremely complex and requires a multitude of controls, control signals, and overrides. To illustrate more clearly the complexity of such a system the control actions during a rapid acceleration from a low power setting to full afterburning are enumerated in sequence:

(1) Power lever at a low power setting, say 25 per cent thrust and the engine running steady state.

(2) Rapid power lever movement to full afterburning.

(3a) The governor, sensing an underspeed condition, tries to increase fuel flow to the maximum available from the fuel pump.

(3b) The acceleration control overrides the governor and limits fuel flow to a safe value.

(3c) The exhaust nozzle control opens the exhaust nozzle as a result of two opening signals, one from the power lever and one from the acceleration control.

(3d) The afterburner control receives a burning signal from the power lever, but this signal is overridden by the r.p.m. signal from the acceleration control.

(3e) The temperature trim signal to the exhaust nozzle control is cut off by the acceleration control.

(3f) The engine begins to accelerate.

(3g) The compressor flow control adjusts the compressor inlet guide vanes and bleed valve as rotor r.p.m. increases.

(4a) When maximum r.p.m. is reached, the governor again assumes control of the engine and reduces fuel flow to the steady-state value.

(4b) The acceleration control sends a trigger signal to the exhaust nozzle control to close the exhaust nozzle even though the power lever is still calling for an open exhaust nozzle.

(4c) The acceleration control sends a trigger signal to the afterburner control which fires the "hot streak" and supplies the afterburner with fuel.

(4d) The temperature trim control is left inoperative because the power lever is in the afterburning position and the afterburning switch has not completed the circuit.

(5a) Afterburner ignition takes place.

(5b) The afterburning switch sends an opening signal to the exhaust nozzle control which opens the exhaust nozzle.

(5c) The afterburning switch sends a signal to the temperature trim control completing the trim signal to the exhaust nozzle control.

(6) If sufficient flight speed is attained, the pressure limiter sends a reduced r.p.m. signal to the all-speed governor and a reduced temperature trim signal to the temperature trim control.

There are various other power lever movements that require different control sequencing. However, their definition is outside the scope of this paper. Obviously, a sincere effort should be made to simplify the modern turbojet engine control system.

Possible Simplification

Fig. 2 illustrates a control system that is expected to control the engine as well as the system in Fig. 1. Yet, the proposed system is less cluttered with interlocking signals, has fewer components, and should be easier to maintain.

Simplification has been accomplished by using the intelligence of the afterburning switch to control the exhaust nozzle. In this capacity, the afterburning switch becomes a turbine pressure ratio exhaust nozzle control. When properly compensated with compressor inlet pressure to modify the effect of low inlet pressures at high altitude (above 35,000 ft. and low flight speeds), the temperature trim control is unnecessary. As an independent turbine pressure ratio is scheduled, the power lever connection to the exhaust nozzle control is no longer needed. By maintaining the scheduled turbine pressure ratio, the exhaust nozzle is automatically

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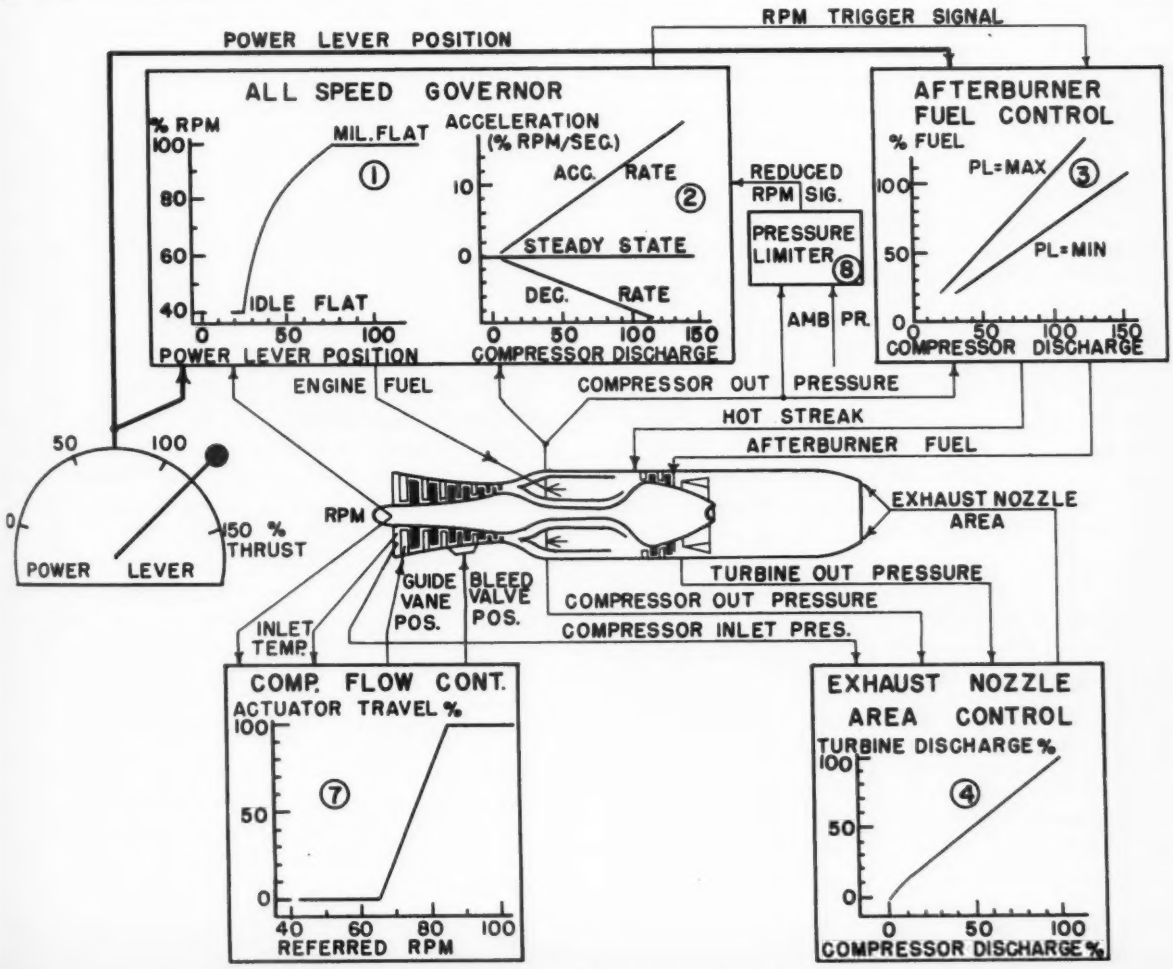

Fig. 2. Simplified control system for a present-day turbojet engine.

Recent NACA Investigations of Noise-Reduction Devices for Full-Scale Engines

A Consideration of Nozzle Shapes, Tailpipe Modifications, and External Devices

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IT IS WELL RECOGNIZED that the operation of aircraft in or near populated areas represents a formidable noise problem. The advent of the jet transport will increase the magnitude of the problem to such an extent that public acceptance is questionable. In view of the already existing public reaction to current noise levels, any increase may well result in drastic action.

Considerable research on jet-engine noise and means for its suppression has been conducted both here and abroad. As a result of this effort, the basic cause of the noise has been determined and its principal components have been isolated. In this respect much credit is due to Lighthill, in England, whose theoretical treatment of the noise generated by a simple jet discharging into quiescent air has shown that the total acoustic power radiated by the jet is directly proportional to the product of the eighth power of the jet velocity and the jet area. These results have been substantiated experimentally by several investigators.[1, 2] When the jet is overchoked to the extent that a strong shock pattern exists in the jet, noise results from both turbulent mixing and shock phenomena. In this case the noise level is greatly increased as the result of an oscillating shock pattern.[3] In general, current jet engines do not have sufficiently high nozzle pressure ratios to cause severe shocks to exist at take-off or climb-out conditions. In high-speed, high-altitude flight, however, such conditions do exist and may cause considerable difficulty as far as cabin noise levels are concerned.

At the NACA Lewis Laboratory we have investigated noise generation of both model jets and full-scale engines, and in both cases we have made measurements in a free field. For example, in the case of the engine (Fig. 1), a thrust stand was located at the edge of an airport in such a manner that there were no obstructions to either the rear or the sides of the engine for over $^1/_2$ mile. The nearest reflecting surface other than a small control room was over 600 ft. in front of the engine. Similarly, the model jet facility was located in a free field where no reflecting surfaces existed within several hundred feet, particularly in the downstream region where the field was unobstructed for a considerable distance.

Fig. 1 shows the measuring stations at which the data were taken for the engine. Sound pressure levels were measured at 100- and 200-ft. radii at 15° intervals around the engine, except in one quadrant where a small building was located which housed the engine controls and equipment for measuring the engine performance. Similarly for the model facility, data were obtained at 15° intervals about the jet axis but at 25-, 50-, or 100-ft. radii.

Some results obtained with both the engine and the air jet are shown in Fig. 2, where the total power level is plotted as a function of the product of the eighth power of the jet velocity and the jet area.** The data for the air jet fall along a single curve with a slope of 10 db. per decade as predicted by Lighthill's theory. Of greater significance here is the fact that the engine data fall on the same curve even though the gas temperatures between the two sets of data varied by approximately 900°F.

From these results it can be seen that the noise generated by a full-scale engine is governed by the same laws as the simple air jet. Since both sets of data fall along a single curve, we may conclude that the principal contribution to jet-engine noise generation arises from the turbulent mixing of the jet with the surrounding atmosphere. In addition, the effect of jet temperature on noise generation appears to be negligible, which agrees with results obtained by Lassiter and Hubbard at the NACA Langley Laboratory.[4]

From the previous discussion it is evident that noise reduction might be achieved by altering the nature or characteristics of the turbulent mixing process, either by a reduction in jet velocity or by changes in the velocity distribution and spreading characteristics of the jet. It is apparent from Fig. 2 that large reductions in power level can be achieved by reducing jet velocity. However, the reduction of jet velocity without thrust reduction requires an increased mass flow through the engine, and to accomplish this without excessive penalties in weight and size may require a specialized engine such as the by-pass engine. This will be discussed in detail in a later section of the paper.

Aside from the reduction of jet velocity, other possible means of noise reduction are dependent on altering the velocity distribution and, hence, the shear gradient of the jet either axially, transversely, or both. A number of devices have been tried and are listed in Table 1.

Presented at the Aircraft Noise Session, 23rd Annual Meeting, IAS, N.Y., Jan. 24–27, 1955.

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† Chief, Physics Division.

‡ Aeronautical Research Scientist.

** The total power level is the total sound power radiated by the engine referred to a reference power of 10^{-13} watts and is obtained by integration of the measured sound pressures.

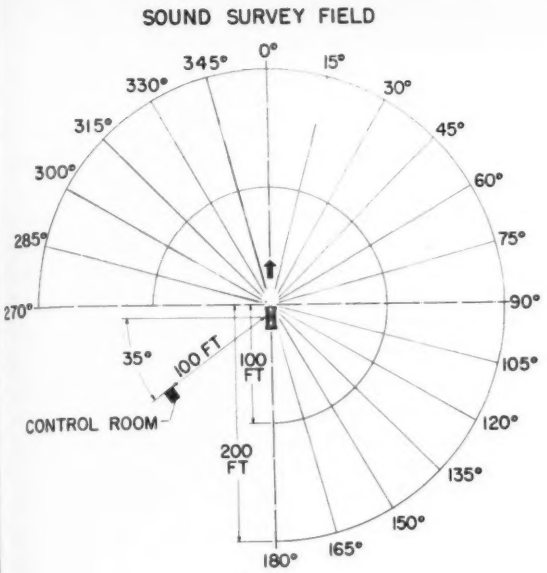

FIG. 1.

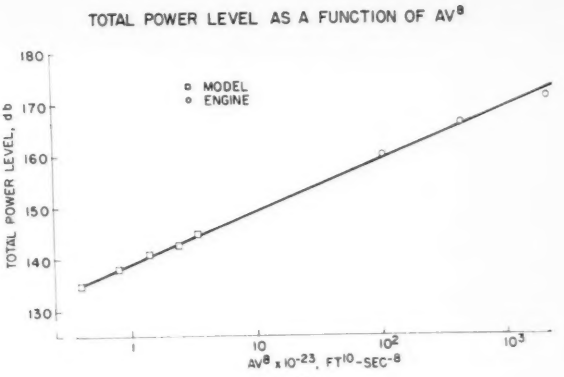

FIG. 2.

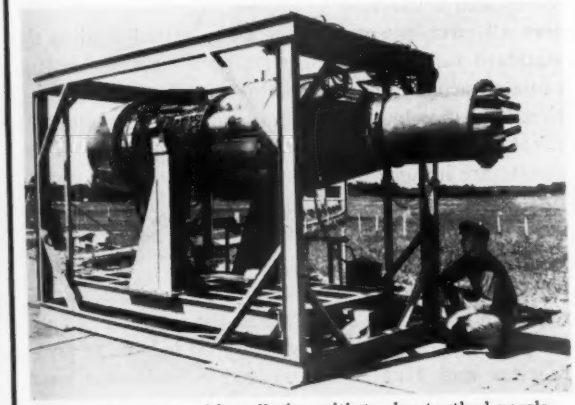

FIG. 3. Thrust stand installation with twelve-toothed nozzle.

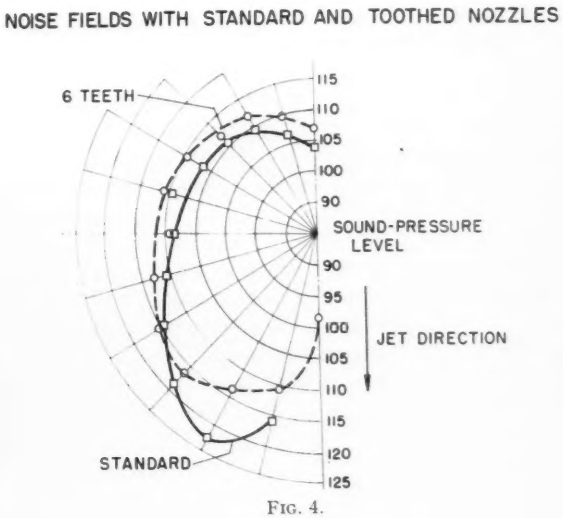

FIG. 4.

NOZZLE	TOTAL ACOUSTIC POWER (db)	THRUST LOSS (PERCENT)
STANDARD	171.1	0
6 TEETH	169.5	2.5
12 TEETH	169.6	6.0

FIG. 5. Noise and thrust with toothed nozzles.

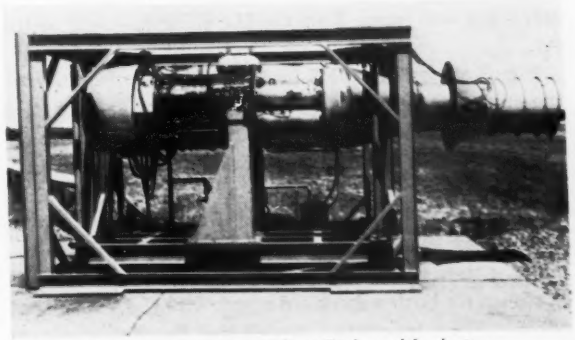

FIG. 6. Thrust stand installation with ejector.

TABLE 1
Noise-Reduction Devices Investigated

Nozzle exit shapes	Circular, square, rectangular, elliptical, truncated
Internal tailpipe modifications	Surface evaporation, vortex generators, air injection, water injection
External devices	Teeth, screens, ejectors

The various nozzle shapes listed were investigated on the model facility with the exception of the truncated nozzle, which was tested on the full-scale engine. The truncated nozzle consisted of a tailpipe cut off at a 30° angle to the jet axis. All the nozzle shapes gave insignificant changes in the sound field in regard to total power radiated, directionality pattern, and frequency spectrum.

The internal modifications to the tailpipe, with the exception of air injection, were made in an effort to soften the shear gradient at the lip of the exit. Surface evaporation consisted in bleeding water into the tailpipe and covering the inside surface with a water film for a distance of 40 in. ahead of the exit, thereby creating an artificially thickened boundary layer of steam. The vortex generators located in the tailpipe about 1 ft. upstream of the exit were designed to serve a similar purpose. The water-injection system was devised to test the absorption of sound energy by water droplets. Fine spray was introduced into the jet just upstream of the exit. The air-injection system[4] was investigated on a model jet and consisted of air injected into the main stream at extremely high pressure as a means of breaking up the shock pattern in an overchoked jet. None of these devices showed significant changes in the sound field at less than critical jet pressure ratios. The air-injection system, however, did show considerable sound reduction at overchoked jet conditions.

The last three items in the table listed as external devices have been subject to considerable research both in the United States and in England. This is particularly true of the toothed devices that were originally investigated by Westley and Lilley[5] in England and since have received much attention. All the investigators to date report essentially the same results, but there is some difference in their interpretation. The toothed nozzles were devised to hasten the jet spreading and hence decrease the shear gradient in the jet.

Fig. 3 shows a typical toothed-nozzle installation in the engine thrust stand. This particular configuration consists of twelve teeth, six parallel to the jet stream and six inclined inward at a 30° angle to the jet stream. A similar nozzle with six square teeth, three parallel to the jet and three inclined inward, was also investigated, and in both cases similar results were obtained.

Fig. 4 shows a polar plot of the sound field at the 200-ft. radius for both a standard nozzle and the six-toothed nozzle. The concentric circles are lines of constant sound pressure level, and the radial lines are the azimuth angles. The jet direction is as indicated; the solid line is the data for the standard nozzle; and the dashed line is for the toothed nozzle. The toothed nozzle shows a decreased sound pressure level of 7 db. at a 30° angle to the jet axis, but increased levels occurred on the sides and forward of the engine. An important point here is that the maximum sound pressure level for the toothed nozzle (60°) is only 5 db. less than the maximum sound pressure level (30°) for the standard nozzle. In fact, the total radiated power in both cases is nearly the same.

Fig. 5 shows the noise and thrust for the toothed nozzles and a standard nozzle. From the figure it can be seen that the toothed nozzles decrease the radiated power by only 1.5 db. This amount is really quite an insignificant decrease from the standpoint of annoyance. The thrust loss with the toothed nozzles is appreciable and is 2.5 per cent for the six-toothed nozzle and 6.0 per cent for the twelve-toothed nozzle. It appears, therefore, that the slight decrease in sound power level is not justified by the loss in performance.

A series of ejectors[6] has been investigated as a means of softening the shear gradient across the jet. A typical ejector mounted on the engine tailpipe in the thrust stand is shown in Fig. 6. The range of ejector configurations investigated is shown in Fig. 7. Two tailpipe- to ejector-diameter ratios, 1.2 and 1.4, were investigated over a range of spacing ratios from 0.15 to 1.50. At rated engine conditions—that is, 100 per cent engine speed and maximum tailpipe temperature—the ejectors all gave essentially the same sound field as the standard tailpipe, and no significant decrease in total radiated acoustic power was measured. It is apparent that the outer low-speed annulus has little suppressive effect on the noise generation of the central jet. These results are in agreement with those of other investigators.[1, 5] In at least one instance, a severe resonance noise was obtained which greatly increased the noise level.

Another suggested noise-reduction device consists of screens placed transversely across the jet at a point near the jet exit. A preliminary study on a 1-in. air jet by Lassiter and Hubbard indicated considerable sound reduction in the area downstream of the jet exit.[4] The full-scale installation is shown in Fig. 8. The screens were held in a circular ring and could be moved longitudinally in a special three-pronged holder, which was mounted on the thrust bed, permitting measurement of the thrust of the engine-screen combination. A number of screen meshes and wire diameters were investigated for a wide range of screen positions.[7] Fig. 9 shows a typical polar sound field for a screen placed approximately $^3/_4$ of an exit diameter downstream of the exit. The data shown are for the 1-in. mesh, $^1/_4$-in. diameter wire screen located 15 in. aft of the jet exit. The sound data were measured at the 200-ft. radius from the jet exit. The direction of the jet is as shown. In the downstream region the sound pressure levels are greatly reduced by the screen. At the 30° position, the sound pressure level is reduced by 13 or 14 db. A comparison of the maximum sound pressure levels for the engine with (111 db.) and without (122 db.) screens shows a

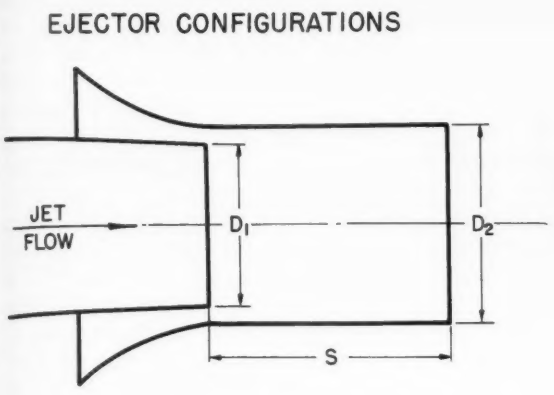

FIG. 7.

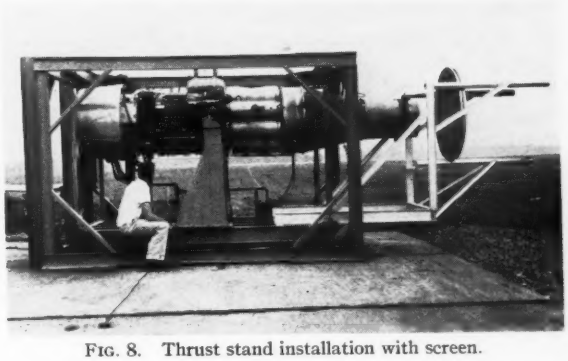

FIG. 8. Thrust stand installation with screen.

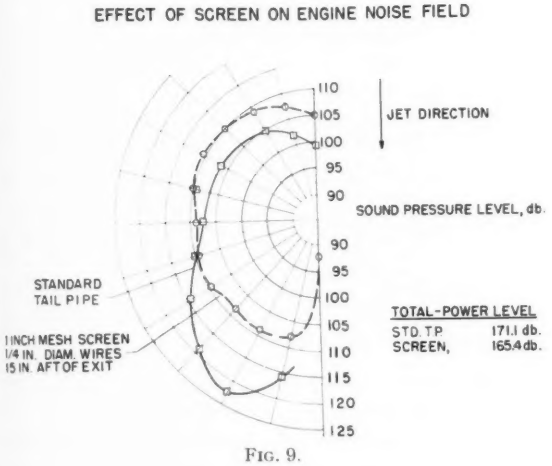
EFFECT OF SCREEN ON ENGINE NOISE FIELD
JET DIRECTION
SOUND PRESSURE LEVEL, db
STANDARD TAIL PIPE
1 INCH MESH SCREEN 1/4 IN. DIAM. WIRES 15 IN. AFT OF EXIT
TOTAL-POWER LEVEL
STD. TP 171.1 db.
SCREEN, 165.4 db.

FIG. 9.

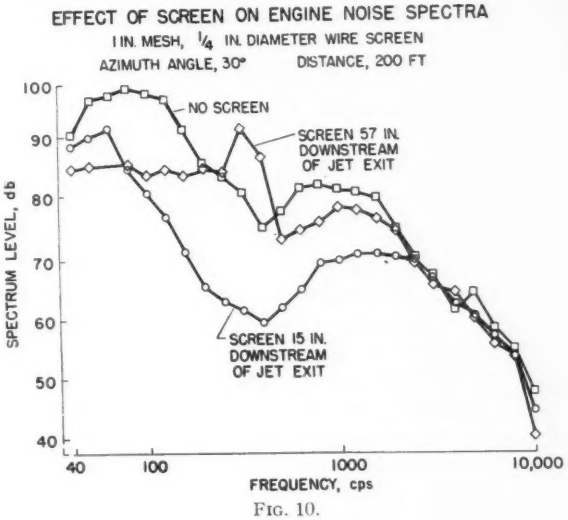
EFFECT OF SCREEN ON ENGINE NOISE SPECTRA
1 IN. MESH, 1/4 IN. DIAMETER WIRE SCREEN
AZIMUTH ANGLE, 30° DISTANCE, 200 FT
NO SCREEN
SCREEN 57 IN. DOWNSTREAM OF JET EXIT
SCREEN 15 IN. DOWNSTREAM OF JET EXIT
SPECTRUM LEVEL, db
FREQUENCY, cps

FIG. 10.

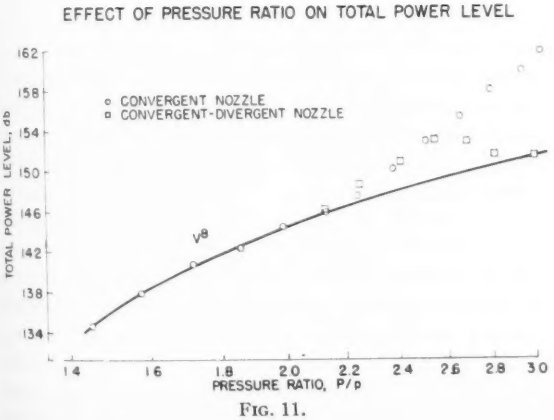

FIG. 11.

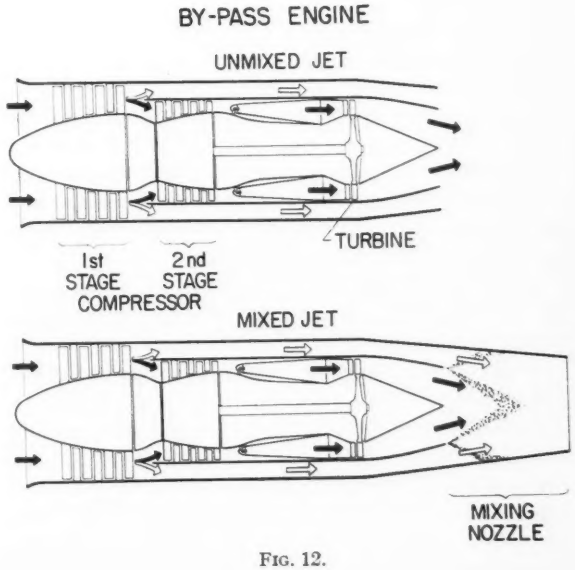

FIG. 12.

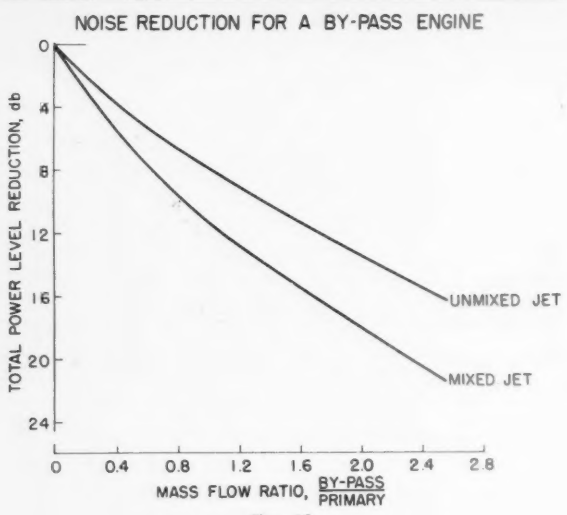

FIG. 13.

decrease of 11 db. This large decrease in the maximum sound pressure level shows that the screens are quite effective noise suppressors.

It should be obvious, however, that the thrust losses with such a system would make it prohibitive for a flight installation; in fact, any screen size that gave appreciable sound reduction gave a thrust loss of 40 per cent or more. Further, the screen position is critical, and, in general, it may be stated that screens of 1 to 4 mesh must be located quite close to the tailpipe (between 6 and 15 in.) in order to provide good noise reduction without resonant noises. This is illustrated in Fig. 10, where the spectrum level is plotted as a function of frequency for a standard nozzle and for the engine and 1-in. mesh, $^1/_4$-in. diameter wire screen combination at two positions. These data were obtained at the 200-ft.-radius, 30°-azimuth-angle position. The screen at the 15-in. position shows a large attenuation of the middle frequency band. At the 57-in. position, however, a sharp resonance at 320 cycles per sec. was encountered. This resonance was of sufficient strength to raise the total power level of the engine screen combination above that for the engine alone. As a matter of experience, the energy contained in this narrow band is extremely irritating from a sound standpoint, and it also caused some structural fatigue of the wires in the screen.

From the previous discussion it appears that screens properly located may prove of considerable value as ground noise suppressors for engine run-up. Their low cost and ready portability make them highly attractive.

In addition to the low-speed, take-off problems discussed herein, it might be well to mention briefly what can be done about noise at the high-speed, high-altitude conditions. This problem is not critical as far as ground personnel and airport vicinities are concerned, but may prove quite intolerable to passengers seated in the rearward sections of aircraft. Further, the extremely high noise levels associated with shock formations in the jet may jeopardize the structural integrity of the aircraft. Fig. 11 shows the power level radiated by a convergent and a convergent-divergent nozzle for a range of jet total- to static-pressure ratios from 1.4 to 3.0. The curve represents the eighth-power law of velocity and was calculated for fully expanded flow. The data for the convergent nozzle show a sharp increase of power level with pressure ratio at a pressure ratio of about 2.1. The convergent-divergent nozzle was designed for a pressure ratio of 3.00, and it can be seen that the data separate from the curve at a pressure ratio of 2.1 but drop down and rejoin the curve near the design pressure ratio. This is interesting since it suggests that Lighthill's relation for turbulent mixing noise may hold at both subsonic and supersonic speeds provided that the flow is shock free. It is evident from Fig. 11 that a considerable decrease in power level can be achieved by using a nozzle designed to provide shock-free expansion of the jet. In addition to the lower noise level, such a nozzle will also provide increased thrust.

It was mentioned earlier that one of the available means of decreasing the noise is by decreasing jet velocity. The idea of derating a turbojet engine—that is, operating it at less than full-rated engine conditions—is extremely unattractive with respect to performance penalties. Along this same line, it would be possible to design a turbojet engine with a lower jet velocity. To provide a similar thrust, however, would require a larger, heavier engine handling more air. Some sample calculations have been made for a transport aircraft using such an engine; and in order to achieve a 9-db. sound power level reduction, it was necessary to reduce the pay load by about 15 per cent for a 2,500 range. It is apparent, therefore, that some other means of reduced jet velocity must be considered as a means of obtaining appreciable noise reduction.

In this respect the by-pass engine offers considerable promise, since it is possible to reduce greatly the jet velocity. A sketch of one possible by-pass engine configuration is shown in Fig. 12. The engine cycle consists of an initial compression stage that handles a large mass of air. After the initial compression stage a portion of the air is by-passed around the engine, and the remaining or primary air is passed through a second compression stage, the combustors, and the turbine. The gas flowing through the internal portion of the engine is required to drive the turbine for both compressor stages, and, in doing so, a great deal more energy per pound of gas is removed as compared with an ordinary turbojet cycle. Consequently, the gas issuing from the inner nozzle is at lower pressure and temperature level and, hence, at a lower velocity than the usual discharge gas from a turbojet engine. In the region aft of the primary jet discharge, there might occur as two extremes either complete mixing or no mixing of the primary and by-pass air. Calculations have been made for a constant thrust by-pass engine cycle, and the sound powers have been determined from the velocities and areas of the discharging gases. For an unmixed

jet it is necessary to add the sound powers of the two jets.

Fig. 13 shows the total power level reduction plotted as a function of the ratio of by-pass to primary air flow for mixed and unmixed jets. A by-pass ratio of zero obviously corresponds to a standard turbojet engine. For either the mixed or unmixed cases it is possible to achieve large reductions in sound power over a comparable thrust turbojet engine—for example, at a by-pass ratio of 1, a decrease of 8 db. is possible for the unmixed jet and 11 for the mixed jet. The additional reduction is due to mixing results from the lower temperature of the mixed gases and the consequent lower velocity. It must be remembered that velocity is the ruling parameter, since power level is a function of velocity to the eighth power.

In addition to the decreased noise levels, the calculations indicated that the specific fuel consumption was less for a by-pass engine, which is an added advantage. As far as weight is concerned, the British have constructed a by-pass engine of weight comparable to an equivalent thrust turbojet engine. At extremely high by-pass ratios the question of compressor whine may become important. It is conceivable that compressor noise may eventually outweigh jet noise; compressor noise is as yet an unexplored area of research.

In summary, a large number of noise-reduction devices have been investigated, but as yet no gadget or piece of hardware exists which can be mounted on the engine to decrease noise in flight.

For ground engine run-up, screens placed transversely across the jet show considerable promise. For high jet pressure ratios the convergent-divergent nozzle is considerably quieter than a convergent nozzle.

A possible solution to the noise problem is a reduction of jet velocity. At least for the case of the jet transport, the by-pass engine gives considerable noise reduction, and it appears that performance of the airplane might actually be improved.

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[3] Powell, A., *On the Mechanism of Choked Jet Noise*, Proc. Phys. Soc., Sect. B, Vol. 66, Pt. 12, No. 408B, pp. 1039–1056, December, 1953.

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[5] Westley, R., and Lilley, G. M., *An Investigation of the Noise Field from a Small Jet and Methods for Its Reduction*, Rep. No. 53, The College of Aeronautics (Cranfield), January, 1952.

[6] North, Warren, *The Jet Velocity Gradient and Its Relation to Turbojet Noise Generation*, proposed NACA RM.

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The Control of Turbojet Engines

(*Continued from page 65*)

sequenced, opened and closed for acceleration and for steady-state nonburning and afterburning operation.

A further simplification is illustrated in Item 2 of Fig. 2. A compressor discharge pressure has been substituted for both the compressor inlet pressure and the temperature signals previously used. Acceleration rate is scheduled versus compressor discharge pressure. This type of control requires a simpler computing mechanism as it uses an engine parameter directly instead of referred parameters.

Conclusion

The control of a "simple" turbojet engine has been shown to be extremely complex. Many of the control functions, such as the compressor flow control, have been necessitated by limitations of the engine. Other control functions, such as the acceleration control, are necessary to relieve the combat pilot of responsibility. Still other control functions, such as the temperature trim control, have been required to maintain optimum engine performance.

Engine and airplane performance must improve in the future to maintain a competitive position in the world picture. This engine and airplane development will undoubtedly require further developments of the control system.

If the turbojet control system is to remain practical, a constant effort must be made to find simple means of doing the job.

Design Considerations for Cargo Aircraft

Analysis of Cargo Handling Related to Air-Frame Design

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Fairchild Engine and Airplane Corporation

Introduction

The purpose of this paper is to discuss some of the design considerations and economic aspects of operating commercial cargo aircraft. It is recognized that the military services are also active in the field of cargo logistics, and, while no attempt is made to discuss military operations, some of the points in this paper could apply to military cargo activities. The presentation is primarily an analysis of cargo handling related to air-frame design. Particular attention is given to aircraft whose cargo load will approach 50,000 lbs.

Current Operation and Trends

Many analyses and forecasts have been made on the possible growth of the commercial air-cargo market. References 1, 2, and 3 contain such detailed prognostications. Fig. 1 shows the domestic freight volume as a function of the average tariff rate. It can be readily seen that the next major improvement in the traffic volume of air cargo awaits the introduction of a more economical airplane. Besides answering the need for a low direct operating cost, a new airplane must provide ease in loading and unloading in order to reduce indirect costs. The increased speed of a new cargo airplane will be an added inducement. This inducement in turn means saving in inventory—i.e., elimination of a surface "pipe line." Furthermore, cases have been cited where the simplified crating and handling costs of air shipment save more than the tariff differential favoring surface shipment. Of course, the ramifications of saving time are already well known.

Design Considerations

Many operators and groups have specified their desires and needs. Individually, each operator has his own set of operating conditions and routes. It is beyond the scope of this paper to itemize all applicable conditions. However, it is recognized that a good cargo airplane must fulfill the needs of the majority of the potential customers if a successful product is to result.

The following paragraphs relate to some specific detailed studies made for cargo aircraft. In general, the results may be considered applicable to any new cargo airplane design. These examples are given to illustrate how air-frame design must be compromised between performance and purpose. Well-proved features such as a separate crew entrance door, easy access to the battery and ground service connections, and cabin pressurization should be carried over to a new cargo airplane.

Loading Entrances

The size and location of cargo doors, while somewhat variable in the past, should now be considered to be a known quantity. Fig. 2 shows the cargo door sizes for two current Lockheed airplanes. It should be noted that the forward left-hand cargo doors are just about the same size. It is interesting to note that the same actuator package is used on both models to raise the door. Because of the nature of the aft fuselage contours, the 1049D has a side outward-opening rear door, while the C-130A opening of the ramp and ramp-door gives a much larger opening. This larger opening is necessary to take advantage of the clear section of the cargo compartment.

Auxiliary Loading Devices

The height of the cargo floor from the ground is certainly a debatable subject. Fig. 3 shows the convenience of loading from truck bed height.

Fig. 4 shows a convenient way of loading even though the cabin floor is relatively high above the ground.

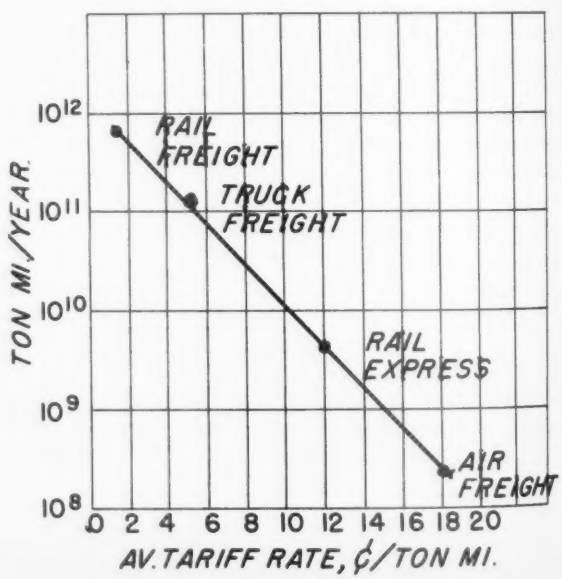


Fig. 1. Domestic freight volume versus rates, 1951.

Presented at the Air Transport Session, 23rd Annual Meeting, IAS, N.Y., Jan. 24–27, 1955.

* Chief Operations Engineer, Fairchild Aircraft Division. Formerly, Preliminary Design Group Engineer, Lockheed Aircraft Corporation, California Division.

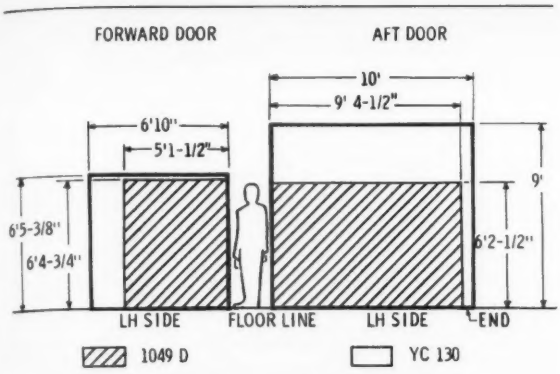


FIG. 2. Cargo door sizes.

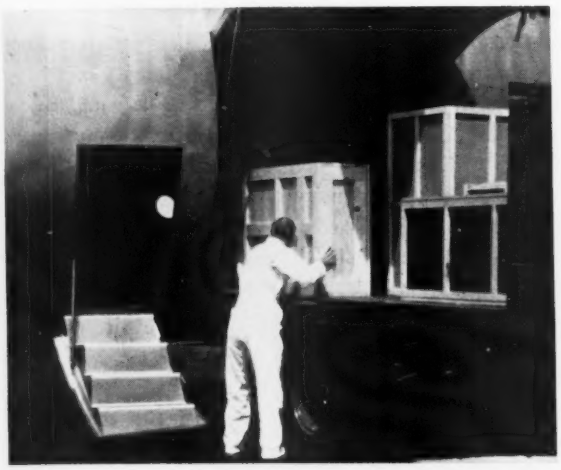


FIG. 3. Loading from truck bed height.

The unit shown is a Lockheed development called the Aerolift. The Aerolift is a mobile, knockdown, air-transportable elevator with which cargo can be quickly raised from ground level to the height of an airplane cargo floor. The 100-sq.ft. loading platform is electrically operated and is capable of lifting a load of 13,500 lbs. The platform can be positioned at any point from ground level to 144 in. above the ground. Castering wheels permit the Aerolift to be towed up to a speed of 8 m.p.h. over unpaved runways.

If desired, the Aerolift can be disassembled in about 30 min. by a four-man crew and stowed in the cargo compartment. The total weight of the unit is 2,200 lbs., no one component weighing over 200 lbs.

Another worth-while approach to loading simplification is the Aerobridge being developed by the Air Terminal Division of Lockheed. A scale model of the Aerobridge is shown in Fig. 5. Electric motors individually drive the wheels that position the Aerobridge to a cargo door opening. The Aerobridge is 69 ft. long when retracted and 84 ft. when extended. It is designed for a loading of 25,000 lbs. The Aerobridge lip that mates with an airplane's cargo floor can be raised from 4 to 13.5 ft. above the ground.

Aft Fuselage Design

The design of an aft fuselage for a cargo airplane is the usual compromise between aerodynamic shape, weight, and design function. Fig. 6 is taken from a particular study in which eight different aft fuselages and door openings were evaluated. This figure is presented to demonstrate the relative cost in performance as balanced against loading convenience. It will be seen that a cargo door giving access to the full cross section of the cargo compartment can be designed into a streamlined aft fuselage. Configuration E shows an aft fuselage originally designed for military air-drop operations. The installation of a streamlined aft fuselage such as shown in Configuration A decreases C_D by 8 per cent when compared to Configuration E. This drag improvement on the streamlined fuselage, Configuration A, represents a 3 1/2 per cent increase in speed or range. Converting this improvement to fuel flow under cruise conditions, a saving of 610 lbs. of fuel can be realized over 1,750 statute miles of cruise distance. For every flight over 1,485 statute miles, a greater weight of fuel is saved than structural weight that was added to the streamlined design.

Ramp Considerations

Present-day commercial cargo airplanes do not have integral loading ramps. However, when a new air-

FIG. 4. Aerolift application.

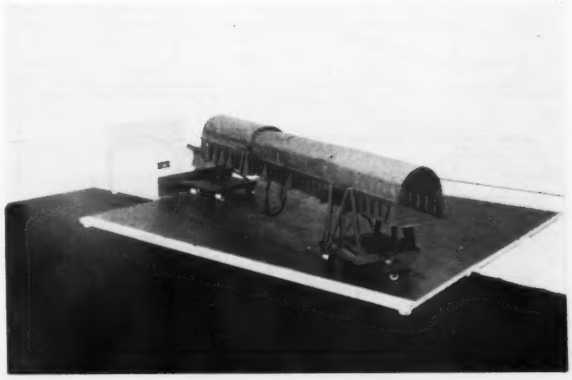


FIG. 5. Aerobridge.

plane can offer a truck bed level floor, the need for an integral ramp is evident. With the addition of structural and aerodynamic improvements, plus the introduction of turbine power plants, such a compromise can be economically justified. The ramp permits loading of an airplane independent of the ground handling devices associated with present aircraft that have cargo floors relatively high off the ground. This represents versatility in that the ramp airplane can be more easily loaded from the ground, docks, or trucks. The hinged ramp permits adjustment in loading from various dock or truck heights. An integral ramp also permits greater utilization of cargo volume by permitting partial storing of cargo in the aft fuselage. Ramp lips over the truck or dock edge prevent tipping of the airplane during loading.

When cargo airplanes become available such that end-loading of large heavy pieces of highway and construction equipment is possible, building contractors will have a new way of rapidly transporting their equipment from one construction project to another. This is illustrated in Fig. 7.

Volume and Density

Assuming the magnitude of pay load is determined for a given design, the cargo volume is directly related to cargo density. In terms of the anticipated cargo market, cargo density tends to be an elusive quantity.

The stated ATA figure[4] for many years has been 10 lbs. per cu.ft. However, with the growth in both military and commercial cargo activity there developed a need to know whether a new value should be used for design studies and presentations.

As a consequence, early in 1953 Slick Airways proposed that a systematic study of their cargo densities be made. Both the Douglas Aircraft Company and the Lockheed Aircraft Corporation agreed to participate in the study. While the final results have not yet been printed, Fig. 8 is presented to indicate that air-cargo density, as expected, has increased. The figure shows that 50 per cent of the items weighed and measured at Slick Airways' Chicago station had a density of 16 lbs. per cu.ft. or lighter. For 80 per cent frequency, the cargo density was 35 lbs. per cu.ft. or lighter.

According to the results of Fig. 8, if a fuselage volume was based on an uncorrected cargo density of 10 lbs. per cu.ft., 75 per cent of all cargo loads could be accommodated before the compartment became space limited. Conversely, if fuselage space is based on an uncorrected cargo density of 20 lbs. per cu.ft., only 38 per cent of all cargo loads could be accommodated. As the weight of the fuselage structure on a large cargo air frame is about 140 lbs. per ft. of fuselage length, a designer cannot afford to design a fuselage for extremely low cargo densities. This means a judicious com-

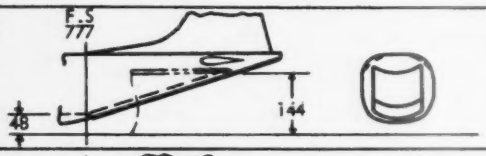
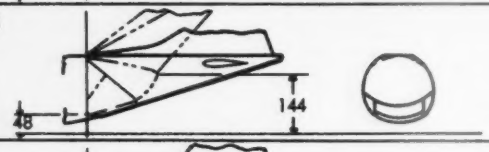
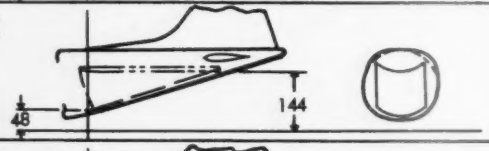
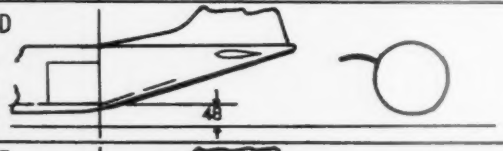
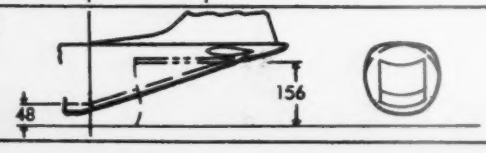
CONFIGURATION	TOTAL AFT FUSE. WEIGHT, % RELATED TO CONFIGURATION E	REMARKS
A 	113.5	LIGHTEST DESIGN WITH THE RAMP AND HAVING BEST EXTERNAL AERODYNAMIC SHAPE. RAMP PERMITS GROUND OR DOCK LOADING
B 	142	TAIL CLEAR OF LOADING OPERATIONS. VULNERABLE TO HIGH WINDS WHEN TAIL IS UP.
C 	92.6	LESS USABLE SPACE FOR CARGO. NO ADJUSTMENT FOR DOCK LOADING; NO INTEGRAL RAMP FOR GROUND LOADING; LIGHTEST DESIGN STUDIED WITHOUT RAMP.
D 	102.5	NO STRAIGHT-IN LOADING POSSIBLE. DISADVANTAGES OF NO RAMP
E 	100.	SUITABLE FOR MILITARY AIR DROP OPERATIONS.

Fig. 6. Aft door loading comparison.

FIG. 7. Road grader inside cargo compartment.

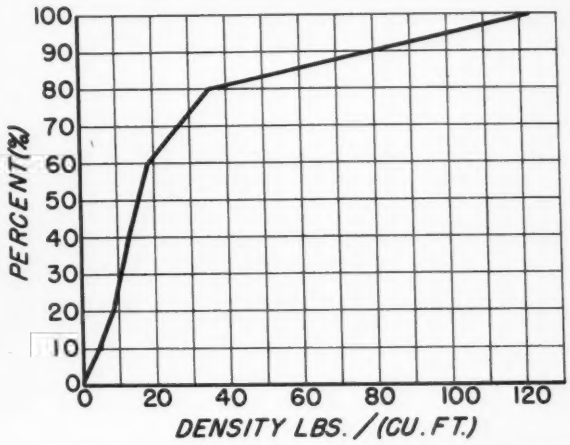


FIG. 8. Lockheed-Douglas-Slick airfreight-type characteristics study; weighted average density distribution (preliminary data).

FIG. 9. Integrally stiffened floor (magnesium-alloy structure).

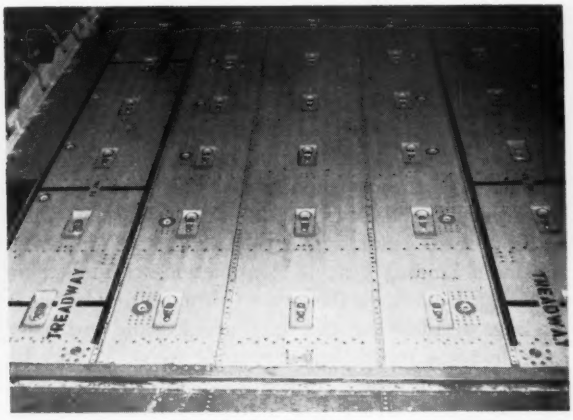


FIG. 10. Integrally stiffened floor (aluminum-alloy structure).

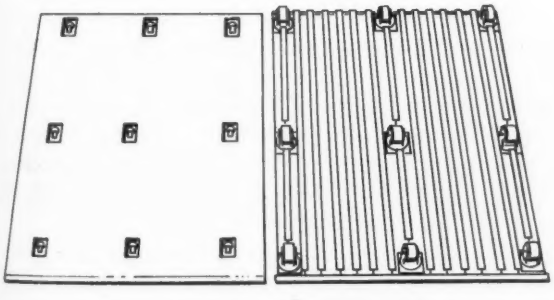


FIG. 11. Universal floor pallet.

HANDLING METHOD	PLACING IN CARGO COMP. (MANHOURS)	TIEDOWN IN AIRPLANE (MANHOURS)	TOTAL MANHOURS	NUMBER OF MEN	ELAPSED TIME (HOURS)
HAND LOADING	20.85 (1)	2	22.85	6	3.8
PALLETS	2.78 (2)	2	4.78	4	1.2
U.F.P.	1.66 (3)	.75	2.41	3	.8

(1) ASSUME LOADING RATE OF 40# /MAN/MIN.

(2) ASSUME LOADING RATE OF 300# /MAN/MIN.

(3) ASSUME LOADING RATE OF 500# /MAN/MIN.

FIG. 12. Cargo loading (50,000-lb. timetable). Airplane floor at truck bed level.

promise must be made between having the compartment either weight limited or space limited.

These values were dockside measurements. When multiplied by a volumetric efficiency factor for the type and shape of cargo compartment to be used, the accurate aircraft load density values will be, in most cases, even greater than those specified in Fig. 8. As an example, for the combination of 50,000 lbs. of pay load and an off-load density of 10, the cubic-foot space required would be 5,000. However, if only a portion of a fuselage cross section can be used—i.e., 0.8 (5,000) = 4,000 cu.ft.—then the space limit results in an effective on-loaded density of 12.5 lbs. per cu.ft.

In addition to density determination, the Lockheed-Douglas-Slick study tabulated other important factors, such as commodity distribution, trip length of shipment, number of pieces in a shipment, etc. The final analysis of these factors is now in preparation.

Cargo Floors

Most floors in currently used cargo airplanes can accommodate loads of 200 lbs. per sq.ft.[5] The 1049D Super Constellation can support 300 lbs. per sq.ft. as well as a running load of 1,000 lbs. per sq.ft. Fig. 9 shows a close-up of a portion of this floor that is constructed of extruded ZK60A-T5 magnesium alloy.

The C-130A military transport has a floor of more rigid construction because of the requirement of carrying heavy wheeled and track-type vehicles. The floor and underneath substructure portions of the fuselage on an airplane like the C-130A are designed to withstand pressure loads, fuselage bending, and support of the main landing gear in conjunction with the skin and rings. Thus, for this type of airplane, uniform floor landings of 1,000 lbs. per sq.ft. are possible with very little increase in fuselage structure weight. For the case studied, the floor and substructure weight would increase about 100 lbs. over a floor suitable for 300 lbs. per sq.ft. loading. For the operation of fork lift trucks, the cargo floor would have adequate strength. Fig. 10 shows the floor design used on the C-130A. It is of integrally stiffened 78S-T6 aluminum-alloy construction. Because of the machined recesses for the tie-down fittings, the tie-down pattern is fixed after initial machining.

The flush track system, which permits selectivity in a longitudinal direction for each individual tie-down fitting, was also investigated. The main disadvantage seems to be the difficulty of keeping the troughs free of dirt and debris. Also, there is a chance of losing the removable tie-down fittings.

Universal Floor Pallet

A proposed device for the efficient handling and movement of commodities from one location to another, both on the ground and in airplanes, is the universal floor pallet (see Fig. 11). The universal floor pallets act in place of a conventional cargo floor when used in an airplane. The units are placed side by side in modules to achieve the desired floor size. Parallel tracks are placed longitudinally in the fuselage to receive the units. Suggested construction for the universal floor pallets is extruded 75S-T6 aluminum alloy with Aerol casters and wheels. Flush tie-down fittings could be incorporated.

The universal floor pallet can be moved on its own wheels, or it can be transported by fork lift trucks. When compared to the conventional floor, the universal floor pallet is at an obvious weight disadvantage. This is due to the fact that the fuselage substructure must be strong enough to permit airplane flights when the removable floor units are left off the airplane. Also, when the universal floor pallets are in place, the tying down of individual units presents some structural discontinuity. A complete set of installed universal floor pallets presents the same smooth floor appearance as a regular fixed floor. If desired, individual loadings can be applied after the empty pallets are locked into the air frame.

For a fair and equivalent situation, the universal floor pallet system must be compared with conventional wooden pallets used on a regular cargo floor. Assuming the comparison is between a 3 ft. by 3 ft. wooden pallet and a 5 ft. by 5 ft. universal floor pallet, the level floor of a particular design study can accommodate 51 wooden pallets or 20 universal floor pallet units. The universal floor pallet system showed a weight penalty of 1,240 lbs. per airplane when compared to the lightest equivalent conventional floor (wooden pallet weight not included). Increased strength to the fuselage floor substructure amounted to 535 lbs. The universal floor pallet units accounted for 705 lbs. of the increase to the basic floor weight. It is interesting to note that a set of nine casters and wheels for one universal floor pallet unit weighs 28 lbs. Adding the weight of the 51 wooden pallets, 1,530 lbs., to the conventional floor makes a weight difference of 290 lbs. in favor of the universal floor pallet. These figures should not be considered as absolute, but they do indicate that the all-metal universal floor pallet can be made competitive to pallets presently in use.

Cargo Handling

The advantage of having a large cargo capacity is questioned by some operators because they believe excessive ground time is required for handling. This belief is true when hand loading—i.e., "bucket brigade"—is used to fill the cargo compartment. However, when palleting systems as well as mechanical handling devices are used, the time of loading is comparable to smaller cargo airplanes.

For a case in point, comparisons can be made between Fig. 12 and the experience of an all-freight carrier using C46 airplanes. This carrier reported that they can on-load 13,000 lbs. of packaged cargo through the door of a C46 in 2 hours. One man operates a fork lift truck to bring the cargo to the level of the door. Three additional cargo handlers work the inside of the cargo

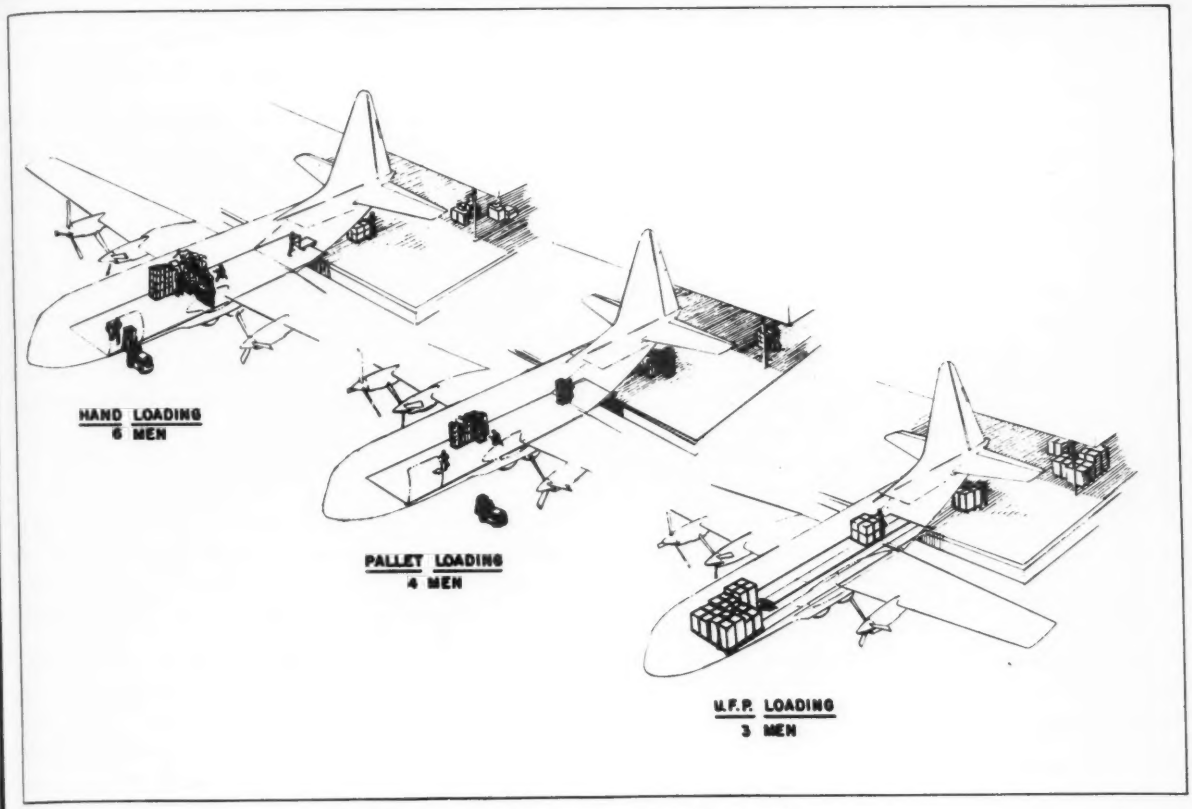


FIG. 13. Cargo loading comparison (three methods).

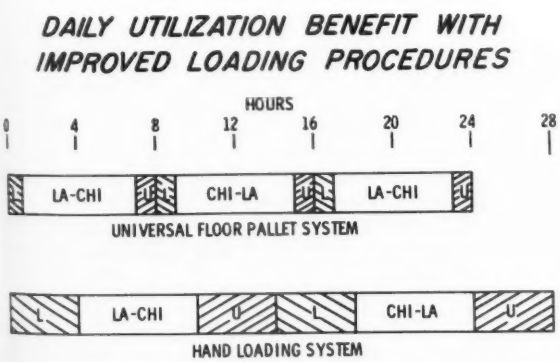


FIG. 14. Daily utilization comparison.

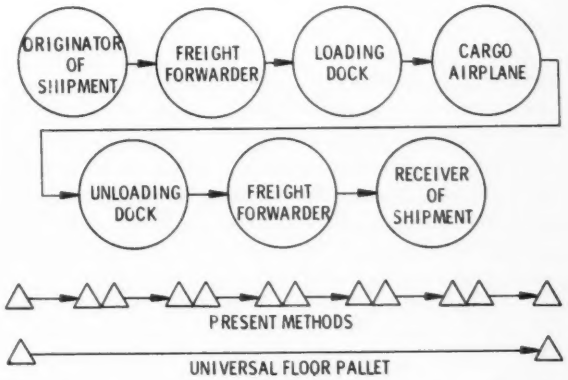


FIG. 15. Comparative flow diagram—conventional versus universal floor pallet.

compartment. For purposes of being fair to the hand loading method, the assumed loading rates in Fig. 12 are a bit arbitrary but still should be considered reasonable. Fig. 13 illustrates the three loading methods tabulated in Fig. 12. The number of men shown for each method in Fig. 13 is assumed to be the minimum required to do the job effectively.

It can be concluded that palleting reduces loading and tying-down time in the airplane. The use of a scheme such as the universal floor pallet should further reduce the time required to load and unload cargo airplanes.

Synonymous with loading time is the need for adequate access to the cargo compartment. Previous discussion in this paper has covered the size of the loading doors. For most methods of cargo loading two doors are required—one at each end of the cargo compartment. If only the universal floor pallet system of loading were to be considered, the forward door might be eliminated with a resultant saving in airplane weight empty.

The real value of the universal floor pallet system can be realized when the benefits are applied to a typical operation. Assuming a combined labor and overhead rate of $5.00 per man-hour, a $200 saving can be made on every turnaround replacing hand loading with the universal floor pallet system. On a flight of 2,000 miles, this means a saving in indirect costs of 10 cents per airplane mile. This is a worth-while saving when it is remembered that current four-engined cargo airplanes have a direct operating cost of about $1.20 per airplane mile over this same distance.

An even larger saving in direct operating costs is realized when every turnaround could reduce ground time from 7.6 hours to 1.6 hours. As shown in Fig. 14, a 6-hour saving per turnaround means that a 300-m.p.h. block speed, 50,000-lb. pay-load airplane loaded with universal floor pallet units could fly a round trip from Los Angeles to Chicago and back again to Chicago in a 24-hour day, while the same airplane loaded by hand would be lucky to make a single round trip in 1 day. This possible increase in utilization from 12 to 18 hours per day would soon pay for the universal floor pallet installation.

Fig. 15 supplements the discussion by showing a flow diagram of the handling operations involved during the transporting of material from origin to destination. This diagram illustrates the elimination of multiple handling operations of the individual package when the universal floor pallet is used. Each delta symbol in Fig. 15 represents a minimum rehandling operation of the item in transit. Such operations as repackaging, placing on a different floor, hand lifting of the package, tying and securing operations, etc., are included. The savings in distribution costs justify serious consideration for a single device that can be a pallet, a ground handling cart, and a portion of a fuselage floor.

Application

To cite a specific economic example, current cargo airplanes, with 30,000 lbs. pay load, can realize total operating costs of 17 cents per ton-mile on the longer flights. Incorporation of the universal floor pallet system into an airplane of this size should permit total operating cost reduction of 3 cents per ton-mile if reduced man-hours and turnaround times are achieved. As related to Fig. 1, domestic freight volume could increase 750 million ton-miles per year. Greater benefits will be derived when turboprop-powered aircraft with pay loads approaching 25 tons are introduced into service.

Conclusion

Domestic air-cargo volume is primarily related to tariff rates. To achieve additional markets, the air lines must use aircraft incorporating such features as:

(1) Loading entrances to permit full utilization of the fuselage cross section.

(2) Cargo floor at truck bed height to permit loading from auxiliary loading devices, docks, or trucks or from the ground via an integral ramp.

(3) A reasonable fuselage volume. No recommendations on a design density are made because of such intangibles as reduced tariff rates tending to attract denser cargo, whether an air line would tend to specialize in handling palleted loads, possible convertibility to passenger carrying, etc.

(4) Cargo floors strong enough to permit wheeled vehicles.

(5) Flush integral tie-down fittings.

(6) An integrated pallet system similar to the universal floor pallet units mentioned in this paper.

(7) Turboprop power plants permitting higher cruising speeds, resulting in reduced operating costs.

When this new equipment is added in service with the air lines, the cargo market will truly begin to grow.

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Take-Off Ground Run of an Airplane with Forced Circulation System of Boundary-Layer Control*

A Study of the Effect of Three Major Parameters on Take-Off Performance

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Cessna Aircraft Company

SUMMARY

Equations for take-off ground run in terms of three parameters:

$$p/P, \Delta w/\Delta p, \text{ and } \Delta C_L/\Delta p$$

are derived for an airplane equipped with the integrated and the independent forced circulation system. In the case of a propeller-driven airplane, the effect of propeller slipstream upon take-off lift coefficient is taken into consideration.

The numerical example illustrating application of the method to a hypothetical small aircraft is presented.

Results indicate that considerable reduction in take-off ground run can be achieved by the application of forced circulation. The results also show the extent to which the system driven by an auxiliary power unit is more effective in reducing take-off ground roll than the system that requires power to be taken from the main engine.

In both cases the improvement in performance is attributed to improvement in effectiveness of flaps when FC is applied. This is manifested by increasing lift and reducing drag during take-off run.

SYMBOLS

a	= horizontal acceleration, ft./sec.²
c	= wing chord at 75 per cent propeller radius, ft.
$\bar{c}$	= wing mean aerodynamic chord, ft.
g	= gravity acceleration
p	= horsepower required by FC system
w	= total weight of the FC system
C_L	= lift coefficient
C_{Lt}	= lift coefficient at take-off (not adjusted for the effect of slipstream)
C_D	= drag coefficient
C_{D_p}	= parasite drag coefficient
D	= drag, lbs.
D	= propeller diameter, ft.
FC	= abbreviation for forced circulation, which is boundary-layer control by sucking or blowing air over deflected trailing-edge flaps
L	= lift, lbs.
P	= horsepower of the main engine
K	= thrust reduction factor
S	= wing area, sq.ft.
S_g	= take-off ground run, ft.
T_0	= static thrust, lbs.
T	= thrust at any velocity, lbs.
V	= velocity, ft./sec.
V_t	= take-off velocity, ft./sec.
W	= gross weight of the airplane, lbs.
$\Delta C_L/\Delta p$	= increase of lift coefficient per horsepower absorbed by FC system
$\Delta w/\Delta p$	= increase of weight per horsepower absorbed by FC system
μ	= coefficient of ground friction
ρ	= mass density of air

Primed symbols indicate that FC system is in operation.

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† Director, Research Department.

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INTRODUCTION

THE PROBLEM OF GROUND RUN during take-off was analyzed and solved many years ago by Diehl and later elaborated upon by others.[1] The basic equations of motion are well understood, and the results are usually given in terms of the net accelerating force and the velocity at take-off.

The application of FC introduces several new factors that affect the length of take-off ground run and, at the same time, complicate evaluation of these factors with respect to their relative importance.

This report is a review of the problem as it is affected by the application of FC in an attempt to analyze the effect of the three major parameters—p/P, $\Delta w/\Delta p$, and $\Delta C_L/\Delta p$—upon take-off performance.

EQUATIONS FOR TAKE-OFF GROUND RUN WITHOUT FC

Assuming that the decrease in static thrust is a function of V^2, or

$$T = T_0 - {}^1/_2\rho V^2 K \tag{1}$$

the ground run of an airplane during take-off can be calculated with sufficient accuracy by

$$S_g = V_t^2/2a \tag{2}$$

where horizontal acceleration

$$a = g/W[T - D - \mu(W - L)] \tag{3}$$

is computed at $V = \sqrt{0.5}\, V_t$.

The numerical value of this constant is based on the fact (verified by numerous flight tests) that the reciprocal of the horizontal acceleration is nearly a linear function of the velocity squared.[2]

Substitution of Eqs. (1) and (3) into Eq. (2) gives:

$$S_g = \frac{W}{\rho g S[(T_0/W - \mu)C_{Lt} - 0.5\,(C_D - \mu C_L + K/S)]} \tag{4}$$

For the given static thrust, gross weight, coefficient of ground friction, and take-off lift coefficient, ground run is a minimum when the term

$$C_D - \mu C_L + K/S$$

vanishes. This term can be written as:

$$C_{D_p} + \beta C_L^2 - \mu C_L + K/S$$

where $\beta = dC_D/dC_L^2$ is a slope of the linearized polar of the airplane. Minimizing this term with respect to C_L we obtain

$$C_L = \mu/2\beta$$

Then, for minimum air and ground resistance, Eq. (4) can be written as:

$$S_g = \frac{W}{\rho g S\{[(T_0/W) - \mu]C_{L_t} - R\}} \tag{5}$$

where $R = 0.5\,[C_{D_p} - (\mu^2/4\beta) + (K/S)]$.

The numerical value of K is obtained from the propeller thrust vs. velocity curve, and C_{D_p} and β are determined from the polar curve of the airplane in the take-off configuration.

Effect of Propeller Slipstream

Up to this point the effect of propeller slipstream has not been taken into consideration, implying that Eq. (5) is applicable only to jet-powered aircraft.

The effect of slipstream upon take-off lift coefficient can be expressed as:

$$\Delta C_{L_S} = NT_c C_L \ (c/\bar{c}) \ (D^2/S) \qquad \text{(reference 5)} \tag{6}$$

where N is a constant, the numerical value of which depends upon flap deflection and the number of propellers.

Since

$$T_c = T/\rho V^2 D^2$$

$$T = T_0 - {}^1/_2\rho V^2 K$$

$$V = \sqrt{0.5}\ V_t$$

Eq. (6) can be written as

$$\Delta C_{L_S} = NC_{L_t}{}^2 \frac{c}{\bar{c}}\left(\frac{T_0}{W} - \frac{K}{2C_{L_t}S}\right) \tag{7}$$

Now, Eq. (5) becomes

$$S_g = \frac{W}{\rho g S\{[(T_0/W) - \mu](C_{L_t} + \Delta C_{L_S}) - R\}} \tag{8}$$

Equations for Take-Off Ground Run with FC

Installation of forced circulation system presents two cases:

(A) Integrated FC system where the main engine of the airplane supplies motive power to pump air for sucking or blowing over the flaps.

(B) Independent FC system where power to pump air is obtained from other sources such as auxiliary power unit.

Equations for take-off ground run with FC system in operation and the criterion for the optimum division of power between the main engine and that absorbed by FC system will be developed for each case.

(I) Jet-Driven Aircraft (Propeller Slipstream Absent)

(A) Integrated FC System

Since a portion of the main engine power is diverted to operate the FC system, the reduced static thrust can be expressed as:

$$T_0' = T_0[1 - (p/P)] \tag{9}$$

Similarly, the increased take-off lift coefficient can be written as:

$$C_{L_t}' = C_{L_t} + (\Delta C_L/\Delta p)p \tag{10}$$

Finally, the increased gross weight due to the installation of the system can be accounted for as:

$$W' = W + (\Delta w/\Delta p)p \tag{11}$$

Substituting Eqs. (9), (10), and (11) into Eq. (5) we obtain:

$$S_g' = \frac{\dfrac{P}{\rho g S}\left[\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}\right]}{\left[\dfrac{T_0\left(1 - \dfrac{p}{P}\right)}{\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}} - \mu P\right]\left[\dfrac{C_{L_t}}{P} + \left(\dfrac{\Delta C_L}{\Delta p}\right)\dfrac{p}{P}\right] - R'} \tag{12}$$

Eqs. (5) and (12) furnish direct comparison of the take-off ground run of an airplane without and with FC when horsepower is diverted from the main engine to operate the FC system.

The optimum division of power, $(p/P)_{\text{opt.}}$, is obtained by minimizing Eq. (12):

$$\left(\frac{p}{P}\right)_{\text{opt.}} = \frac{\dfrac{\Delta C_L}{\Delta w}\cdot\dfrac{W}{P}(T_0 - \mu W) - \dfrac{C_{L_t}}{P}(2T_0 - \mu W) - \dfrac{W}{P}\left(T_0\dfrac{C_{L_t}}{P}\cdot\dfrac{\Delta p}{\Delta w} - R'\right)}{\dfrac{\Delta C_L}{\Delta p}(T_0 + \mu W) - \dfrac{\Delta w}{\Delta p}(\mu C_{L_t} + R') + T_0\left(\dfrac{2W}{P}\cdot\dfrac{\Delta C_L}{\Delta w} - \dfrac{C_{L_t}}{P}\right)} \tag{13}$$

where

$$\Delta C_L/\Delta w = \Delta C_L/\Delta p \cdot \Delta p/\Delta w$$

The shortest take-off ground run, Sg' min., can be calculated by substituting numerical value of $(p/P)_{\text{opt.}}$ into Eq. (12).

(B) Independent System

Since in this case power to operate the system is not taken off the main engine, Eq. (9) reduces to $T_0' = T_0$. Then Eq. (12) takes the following form:

$$S_g'' = \frac{\dfrac{P}{\rho g S}\left[\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}\right]}{\left[\dfrac{T_0}{\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}} - \mu P\right]\left[\dfrac{C_{Lt}}{P} + \left(\dfrac{\Delta C_L}{\Delta p}\right)\dfrac{p}{P}\right] - R''} \tag{14}$$

Eqs. (5) and (14) allow comparison of the take-off ground run of an airplane without and with FC when power to operate FC system is supplied by an auxiliary power plant.

Again, if the optimum division of power is desired, Eq. (14) is minimized:

$$\left(\frac{p}{P}\right)_{\text{opt.}} = \frac{\dfrac{\Delta C_L}{\Delta w}\dfrac{W}{P}(T_0 - \mu W) - \dfrac{C_{Lt}}{p}(2T_0 - \mu W) + \dfrac{W}{P}R''}{\dfrac{\Delta C_L}{\Delta p}(T_0 + \mu W) - \dfrac{\Delta w}{\Delta p}(R'' + \mu C_{Lt})} \tag{15}$$

The shortest take-off ground run can be obtained by substituting numerical value of $(p/P)_{\text{opt.}}$ into Eq. (14). Eqs. (12) and (14) provide a convenient means to study the effect of the three major parameters—p/P, $\Delta C_L \div \Delta p$, and $\Delta w/\Delta p$—upon take-off ground run.

(II) Propeller-Driven Aircraft (Slipstream Present)

(A) Integrated System

Substitution of Eqs. (9), (10), and (11) into Eq. (8) yields:

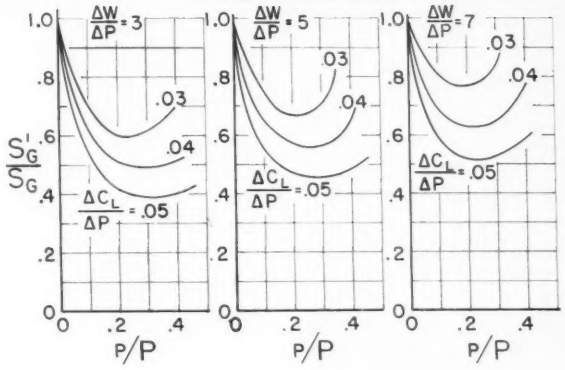
$$S_g' = \frac{\dfrac{P}{\rho g S}\left[\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}\right]}{\left[\dfrac{T_0\left(1 - \dfrac{p}{P}\right)}{\dfrac{W}{P} - \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}} - \mu P\right]\left[\dfrac{C_{Lt}}{P} + \dfrac{\Delta C_{Ls}}{P} + \left(\dfrac{\Delta C_L}{\Delta p}\right)\dfrac{p}{P}\right] - R'} \tag{16}$$

where

$$\frac{\Delta C_{Ls}}{P} = N\frac{c}{\bar{c}}\left[\frac{C_{Lt}}{P} + \left(\frac{\Delta C_L}{\Delta p}\right)\frac{p}{P}\right]^2 \times \left\{\frac{T_0\left(1 - \dfrac{p}{P}\right)}{\dfrac{W}{P} + \left(\dfrac{\Delta w}{\Delta p}\right)\dfrac{p}{P}} - \frac{K}{2S\left[\dfrac{C_{Lt}}{P} + \left(\dfrac{\Delta C_L}{\Delta p}\right)\dfrac{p}{P}\right]}\right\}$$

Differentiation of Eq. (16) leads to a cumbersome expression and therefore is not presented here. The optimum (p/P) and therefore the minimum ground run can be calculated by solving Eq. (16) for several values of p/P.

FIGURE 1
PROPELLER DRIVEN AIRCRAFT
INTEGRATED SYSTEM



(B) Independent System

As before, in this case $T_0' = T_0$ and Eq. (16) is still valid provided that term $[1 - (p/P)]$ is eliminated.

Numerical Example*

The following numerical constants were used in order to illustrate the application of formulas derived in this analysis:

W	= 2,000 lbs.
S	= 175 sq.ft.
P	= 200
T_0	= 1,000 lbs.
μ	= 0.05
N	= 0.6
R	≒ 0.200 (without FC)
R'	= 0.150 (with FC)
C_{Lt}	= 1.5
$\Delta w/\Delta p$	= 3, 5, and 7
$\Delta C_L/\Delta p$	= 0.03, 0.04, and 0.05

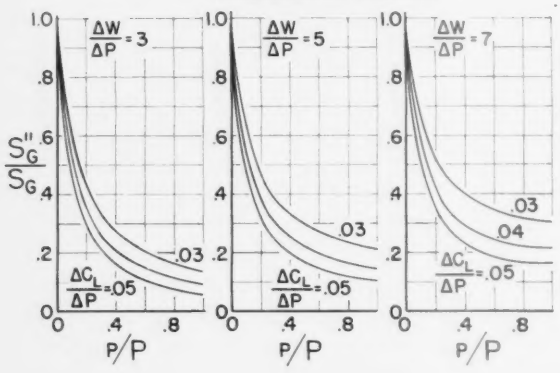
The constants listed above were inserted in Eqs. (12), (14), and (16). The equations were solved for values of p/P ranging from 0 to 1.0, and results for the piston-engine-powered airplane are presented in Figs. 1 and 2. The curves for jet-driven airplanes are extremely similar and therefore are not presented.

Conclusions

Figs. 1 and 2 show that in general FC, by improving flap effectiveness, is a powerful means of reducing take-off run of an airplane. In particular, the independent system, driven by an auxiliary power unit, holds more promise than the integrated system under the same conditions.

* Acknowledgment is made to J. L. Smith for checking the equations and for preparation of the numerical example.

FIGURE 2
PROPELLER DRIVEN AIRCRAFT
INDEPENDENT SYSTEM



It should be borne in mind that reduction in ground run during take-off, presented in Figs. 1 and 2, is calculated on the assumption of constant $\Delta C_L/\Delta p$.

However, two-dimensional wind-tunnel tests indicate that $\Delta C_L/\Delta p$ decreases as C_{L_t} increases. The exact relationship, depending upon geometry of the slot and flap arrangement, does not lend itself easily to mathematical treatment and therefore is not incorporated in this analysis. For this reason, the results here are considered as optimum and should be adjusted by checking against $\Delta C_L/\Delta p$ parameter obtained in wind-tunnel test of a specific wing configuration.

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[1] Diehl, W. S., *The Calculation of Take-off Run*, NACA TR 450, 1931.

[2] Hartman, E., *Consideration of the Take-off Problem*, NACA TN 557, 1936.

[3] Wetmore, J., *Calculated Effect of Various Types of Flap on Take-off Over Obstacles*, NACA TN 568, 1936.

[4] Horton, Elmer A., and Quinn, John H., Jr., *Analysis of the Effect of Boundary-Layer Control on the Take-off and Power-off Landing Performance Characteristics of a Liaison Type Airplane*, NACA TR 1057, 1951.

[5] Weil, Joseph, and Sleeman, William C., Jr., *Prediction of the Effects of Propeller Operation on the Static Longitudinal Stability of Single Engine Tractor Monoplanes with Flaps Retracted*, NACA TN 1722, 1948.

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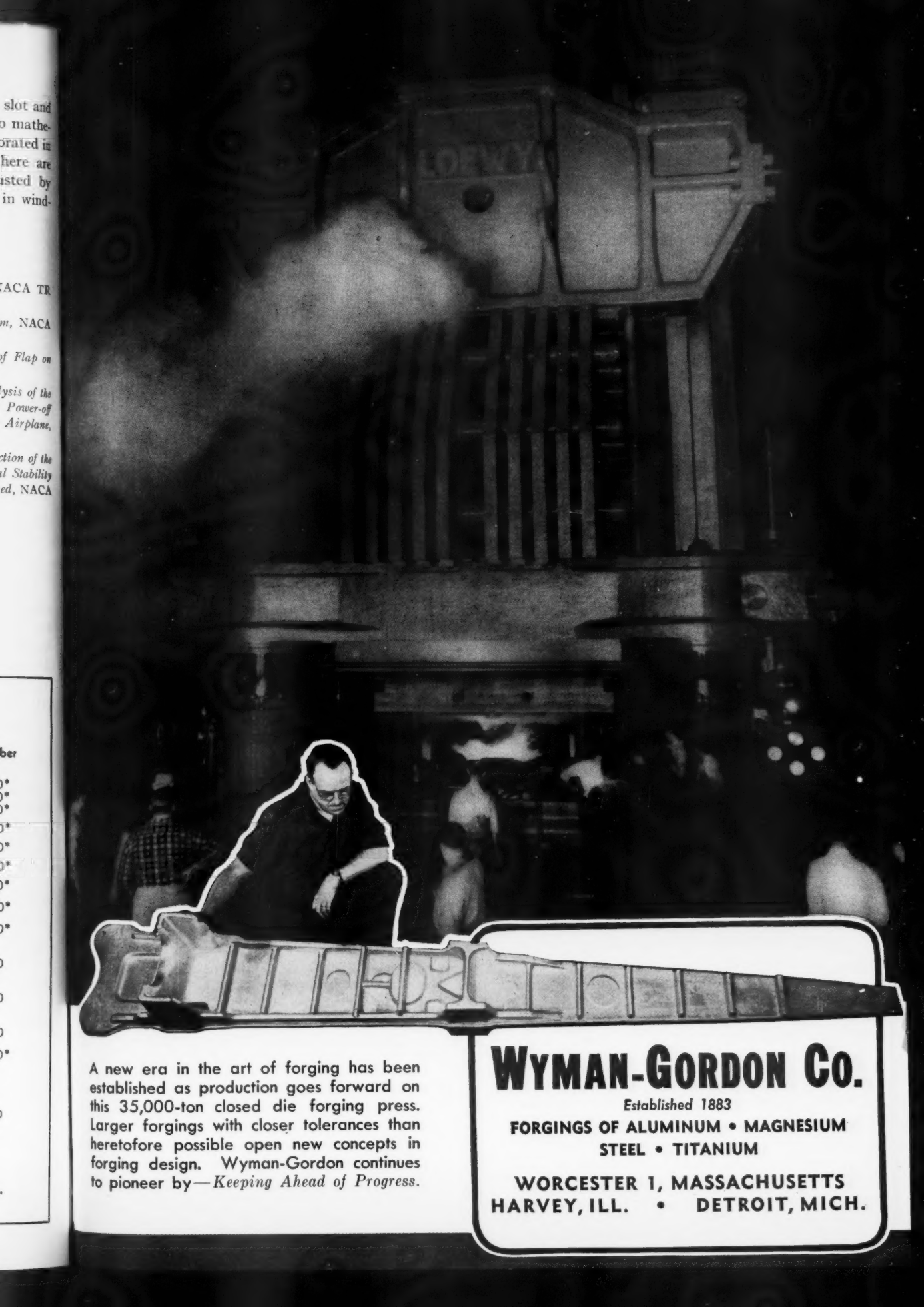

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IAS News

(*Continued from page 39*)

Company, has been appointed to the NACA's Committee on Power Plants for Aircraft.

▸ **Hugh L. Dryden** (HF), Director of the NACA and Past-President, IAS, was awarded the honorary degree of Doctor of Engineering by the University of Maryland on March 25.

▸ **John C. Evvard** (M), of Lewis Flight Propulsion Laboratory, NACA, has been elected to the Executive Committee of the Division of Fluid Dynamics of the American Physical Society.

▸ **F. N. Frenkiel** (AF), of the Johns Hopkins Applied Physics Laboratory, has been elected Secretary-Treasurer of the Division of Fluid Dynamics of the American Physical Society. He was previously Chairman.

▸ **Cramer W. LaPierre** (M), Vice-President in charge of the Atomic Energy and Defense Products Group, General Electric Company, has been named Chairman of the NACA's Industry Consulting Committee.

▸ **Hans W. Liepmann** (F), Professor of Aeronautics, California Institute of Technology, has been elected to the Executive Committee of the Division of Fluid Dynamics of the American Physical Society.

▸ **Dr. Randolph Lovelace II** (F), Director of Lovelace Foundation for Medical Education and Research, has been elected to the Board of Governors of Flight Safety Foundation, Inc. He is a member of the USAF Scientific Advisory Board.

▸ **Charles Marcus** (AM), Vice-President, Bendix Aviation Corporation, was Chairman of the Aircraft Manufacturers Division of the 1955 April Cancer Crusade of the New York City Cancer Committee.

▸ **Milton S. Plesset** (AF), Professor of Applied Mechanics, California Institute of Technology, was engaged by the Convair Division of General Dynamics Corporation as a Consultant in the fields of mathematics and aerodynamics.

▸ **Frederick F. Robinson** (AM), President of National Aviation Corporation, has been elected to the Board of Governors of Flight Safety Foundation, Inc.

▸ **Norbert E. Rowe** (F), Technical Director, Blackburn and General Aircraft Ltd., has been presented a Diploma of Fellowship by the Council of the City and Guilds of London Institute.

▸ **Galen B. Schubauer** (F), Chief, Fluid Mechanics Section, National Bureau of Standards, has been elected Vice-Chairman of the Division of Fluid Dynamics of the American Physical Society.

Howard E. Roberts, AFIAS, has been appointed General Manager of the American Helicopter Division, Fairchild Engine and Airplane Corporation. He was formerly Director of Operations at the Manhattan Beach, Calif., plant.

▸ **R. Dixon Speas** (AF), Owner, R. Dixon Speas, has been elected to the Board of Governors of Flight Safety Foundation, Inc.

▸ **Theodore von Kármán** (HF), Chairman, Advisory Group for Aeronautical Research and Development, NATO, has been engaged by Convair Division of General Dynamics Corporation as a Consultant on mathematics and aerodynamics.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are therefore urged to notify the News Editor of changes as soon as they occur.

L. M. Chattler (M), Chief Engineer, National Water Lift Company, Kalamazoo, Mich. Formerly with Navy Bureau of Aeronautics, Washington.

Peter W. D'Anna (AF), Preliminary Design Group Leader, Design Development Group, Goodyear Aircraft Corporation. Formerly with Air Arm Division, Westinghouse Electric Corporation.

Clifton T. Foss (M), Vice-President and General Manager, Arma Division, American Bosch Arma Corporation. Formerly, Vice-President—Engineering and Assistant General Manager, Arma Division.

George E. Fouch (M), General Manager, Evendale Operating Department, Aircraft Gas Turbine Division, General Electric Company. Formerly, General Manager, Jet Engine Department, Aircraft Gas Turbine Division.

Clifford C. Furnas (F), Chancellor of the University of Buffalo, is serving as consultant on chemistry to Avco Manufacturing Corporation.

Charles S. Glasgow (AF), Assistant Chief Engineer, Long Beach Division, Douglas Aircraft Company, Inc. Formerly, Chief Tool Engineer, Santa Monica Division, Douglas.

Sydney J. Goldberg (M), Engineering Staff Assistant to Assistant Chief Engineer, Analytical Engineering Division, Northrop Aircraft, Inc. Formerly, Group Leader, Flight Test Equipment Engineering, North American Aviation, Inc.

Ernest C. Hartmann (AF), Assistant Director of Research, Aluminum Research Laboratories, Aluminum Company of America. Formerly, Chief, Engineering Design Division, Aluminum Research Laboratories.

Lewis H. Height (M), Chief Project Engineer, Georgia Division, Lockheed Aircraft Corporation. Formerly, Project Engineer for P2V Neptune, California Division, Lockheed.

Lester J. Henderson (AM), Vice-President, Aviation Division, The Weatherhead Company, Antwerp, Ohio. Formerly, Sales Manager, Aviation and Industrial Division, The Weatherhead Company.

Joseph S. Islinger (TM), Research Engineer, Materials Engineering Section, Armour Research Foundation, Illinois Institute of Technology. Formerly, Associate Engineer, Materials Engineering Section.

Kazimierz T. Ksieski (M), with Parker Aircraft Company. Formerly, Chief Research Engineer, Aero Supply Manufacturing Company, Inc.

Herbert P. Lindblad (M), Vice-President and Chief Engineer, Colonial Aircraft Corporation. Formerly, Project Structural Design Engineer, Republic Aviation Corporation.

Raymond B. Maloy (AF), Aircraft Engineering Adviser, International Region, CAA, Paris, France. Formerly, Chief, Flight Test Branch, CAA, Washington, D.C.

William F. Moore (M), Manager—Marketing, Aircraft Accessory Turbine Department, General Electric Company, Lynn, Mass. Formerly, Manager—Aviation, Seattle and Northwest District, G-E.

Marvin L. Nelson (M), Assistant Manager of Manufacturing, Solar Aircraft Company, San Diego. Formerly, Manager, Quality Control Division, Solar's Des Moines plant.

Gerhard Neumann (M), General Manager, Jet Engine Department, Aircraft Gas Turbine Division, General Electric Company. Formerly, Manager, Development Engine Section, Aircraft Gas Turbine Division.

Stanley N. Opatowsky (TM), Second Lieutenant USAF, Aeronautical Engineer, Power Plants Unit, Components Test Section, Test Engineering Branch, Directorate of Flight and All-Weather Testing, Wright Air Development Center. Formerly, Flight Research Engineer, Sikorsky Aircraft Division, United Aircraft Corporation.

Frederick W. Schwartz, Jr. (M), with Booz, Allen & Hamilton, Management Consultants, Chicago. Formerly, Chief Structural Design Engineer, Flight Refueling, Inc.

William R. Sears (F), Director of the Graduate School of Aeronautical Engineering, Cornell University, has been engaged by Avco Manufacturing Corporation as consultant on aeronautical engineering.

James L. Straight (AM), now with the public relations staff, Lear, Incorporated. Formerly with the California Manufacturers Association.

David B. Thurston (AF), President, Colonial Aircraft Corporation. Formerly, Preliminary Design Engineer, Propeller-Driven Aircraft, Grumman Aircraft Engineering Corporation.

Carlos C. Wood (F), Chief Engineer, Long Beach Division, Douglas Aircraft Company, Inc. Formerly, Chief, Preliminary Design Section, Santa Monica Division, Douglas.

George F. Worley (M), Chief of Preliminary Design, Douglas Aircraft Company, Inc. Formerly, Assistant, Aerodynamics Section, Douglas.

Corporate Member News

• **Aerojet-General Corporation, Subsidiary of The General Tire & Rubber Company.** . .The Air Force plans to build a Rocket Engine Test Facility at Fort Crowder, Mo., which will be operated by Aerojet-General and will employ at least 500 persons. . . .Aerojet-General is sponsoring combustion studies on solid propellants for rockets at Princeton University's James Forrestal Research Center. Object of the research is to make possible closer control of the firing performance of solid-propellant rockets.

• **Aeroquip Corporation.** . .Marman Products, Inc., of Los Angeles, has been purchased by Aeroquip.

• **Air Associates, Inc.** . . .A small, rotating red warning light for use on private planes and executive aircraft is being distributed by this company. The light weighs 23 oz. and produces 80 to 100 flashes per min.

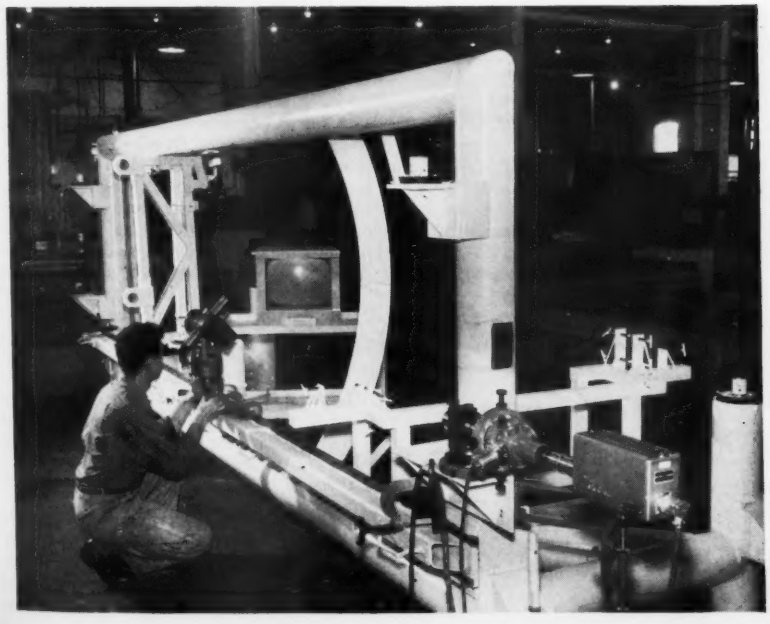
• **Airborne Accessories Corporation.** . . The company has acquired an adjoining building, increasing floor space 50 per cent.

• **Aircraft Radio Corporation.** . .New on the market are the F-13 audio amplifier, designed to power one or more loud speakers in the cockpit of an airplane, and the A-17 antenna coupler, designed to couple an air-borne dipole antenna into a 52-ohm coax cable over a band of 108 to 125 mc. The output from several radio receivers may be fed into the F-13 for simultaneous monitoring.

• **AiResearch Manufacturing Company, The Garrett Corporation.** . .The National Safety Council presented its Award of Honor to AiResearch for a record of only eleven lost-time injuries in over 10,000,000 work-hours in 1954. It was the company's second Award of Honor within a year.

• **Allis-Chalmers Manufacturing Company.** . .President W. A. Roberts died April 12 at the age of 57. He had been with the company since 1924.

Substituting closed-circuit television parts for a man's eye has increased 300 times the accuracy of the assembly jigs on which Douglas Aircraft Company, Inc., is building the DC-7C transport. The system uses telescopes and targets for the optical reference lines from which parts of the jigs are positioned. The television camera *(right)* is aimed at the eye piece of the jig transit. The target image is enlarged 300 times on the television screen, enabling the operator to adjust the optical square quickly and accurately.



• **Allison Division, General Motors Corporation.** . .A $75,000,000 expansion program will give Allison "the most modern gas turbine aircraft engine development center under private operation anywhere in the world," the company announced recently. Plans call for new engineering, research, and testing facilities for the development of high-performance turboprop and turbojet aircraft engines for military and commercial use. The new facilities will be constructed on a 95-acre site in Indianapolis, and the total area devoted to engine research will be increased from the present 500,000 sq.ft. to nearly 1,000,000 sq.ft. The staff required for aircraft engine development will be increased by approximately 40 per cent, the company said, with engineering and technical personnel filling most of the new jobs. GM expects to begin construction this year and complete the entire program by 1959.

• **Aluminum Company of America.** . .A 50,000-ton forging press and a 35,000-ton press are producing large, one-piece structural parts for aircraft, using light metals, at a new plant operated by Alcoa in Cleveland. The $40,000,000 facility, sponsored by the USAF heavy press program, was dedicated May 5 by Air Force Secretary Talbott. . . .Alcoa's annual report stated that a major expansion program, begun in 1951 and involving capital expenditures of about $360,000,000, was essentially completed in 1954.

• **Avien, Inc.** . . .A wing is under construction at the plant in Woodside, N.Y., to house an engineering test laboratory, materials laboratory, product-display room, and school room.

• **Bell Aircraft Corporation.** . .An automatic carrier-landing system that is expected to permit "hands off" landings aboard a carrier in bad weather, or if the pilot is wounded, has been developed and tested. The mobile radio-radar unit includes an electronic computer and is easily transportable by air. . . .O. A. Pfaff, President and General Manager, American Wheelabrator & Equipment Corporation, has been elected to Bell's Board of Directors. American Wheelabrator has been affiliated with Bell since June of 1954.

• **Bendix Aviation Corporation.** . .Bendix Radio Division is marketing an audio control panel that is said to represent the first use of transistors in communications equipment for air-line transport planes. To avoid errors, three different types of switches are used for transmitting, filter selection, and receiving.

• **Boeing Airplane Company.** . .A flight-test communications system that the company claims is "the most complete in the American aviation industry" has been placed in operation at Boeing's new $5,800,000 flight-test center. The apparatus includes 18 radio transmitters, 26 radio receivers, and 35 antennas. Contact can be maintained with planes up to 250 miles away.

• **The Cessna Aircraft Company.** . .A twin-engined Cessna 310 was recently flown from Wichita, Kan., to Zurich, Switzerland, for delivery to a purchaser. The route was via New York, Gander, Greenland, Iceland, and Scotland.

Kearfott RDF Loops Exceed 41,000 Hours Operation

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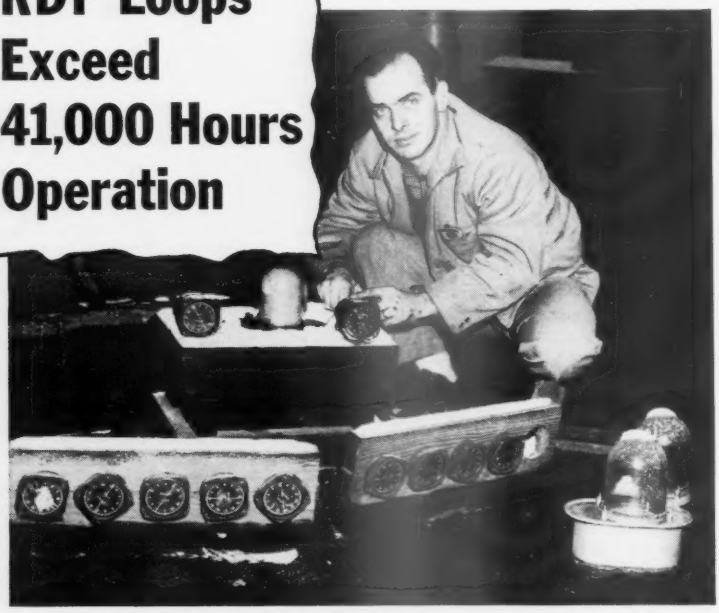

The Kearfott AS-313 Radio Direction Finder Loop and the ID-90 Indicators withstood continuous operation for 41,977 hours. This is over 40 times the 1,000 hours required by Air Force specifications for Sealed Aircraft instruments.

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• **Convair Division of General Dynamics Corporation. . .**A $3,500,000 wind tunnel capable of air speeds between $\frac{1}{2}$ and $4\frac{1}{2}$ times the speed of sound is to be built at the San Diego plant. Construction is expected to take 2 years. The trisonic tunnel will be used to test models of aircraft and guided missiles. It will be of the blowdown type, with an average run of 40 sec. The test section will be 4 ft. square. . . .Convair will develop the aircraft industry's first electronically controlled milling machine, under an Air Force contract. The 200-ton machine and its electronic system will be completed in about 18 months, the company announced. A computer will translate engineering data into numerical commands to which the milling machine will respond. These commands, recorded on magnetic tape, will guide its four cutting heads, bed, and turntable. The revolutionary machine is expected to reduce tool engineering lead time considerably and assure perfect quality control. . . .According to mid-March reports, 14 scientists have been engaged by Convair as Consultants on special problems in military aircraft and missile systems and on problems of basic nuclear research and industrial applications of nuclear power. Six of the 14 are Consultants in the field of theoretical physics; they are Hans Bethe, Cornell University; Kenneth M. Case, University of Michigan; Charles L. Critchfield, University of Minnesota; Clark M. Mills, University of California; Edward Teller, University of California; and John A. Wheeler, Princeton University. Robert F. Mehl, Carnegie Institute of Technology, and Frederick Seitz, University of Illinois, are Consultants in metallurgy and theory of metals. Lan Jen Chu, Massachusetts Institute of Technology, is a Consultant in experimental physics and electronics. Covering the mathematics and aerodynamics fields are Richard Courant and Peter D. Lax, New York University; Milton S. Plesset, AFIAS, California Institute of Technology; and Theodore von Kármán, HFIAS, Chairman of AGARD, NATO. Fred L. Whipple, Harvard University, is Consultant in astrophysics. Frederic de Hoffman recently left Los Alamos Scientific Laboratory to join Convair as Assistant Vice-President for nuclear planning.

• **Cornell Aeronautical Laboratory, Inc. . . .** The Laboratory's Physics Department, in a contract for the U.S. Navy, is studying a method of detecting the location of the jet stream. The first phase of this project is the instrumentation of aircraft with equipment to measure electrostatic phenomena suspected of being associated with the jet stream. It has been argued that an electrostatic field appears at the earth's surface when a jet stream axis is within 150 to 200 miles of the observing station. This phase of the Navy-C.A.L. program—i.e., the installation of electrostatic measuring equipment in an airplane and its flight in or near the stream—is expected to verify or disprove the electrification theory.

• **Curtiss-Wright Corporation. . .**More than 5,000 J65 turbojet engines have been manufactured, the corporation announced on April 8. Currently used in eight high-speed fighters and bombers, the J65 is

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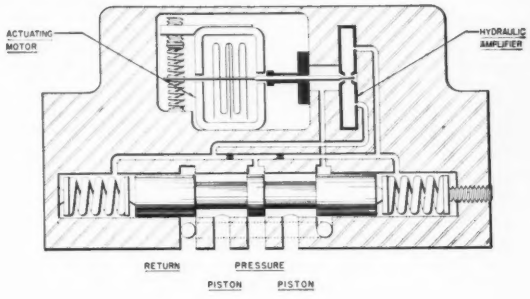
Conventionally, valve input is from a balanced push-pull DC amplifier and valve flow output is applied to a piston or hydraulic motor. An electric signal proportional to piston position or motor angular rotation is fed back to the amplifier to give a closed servo loop.



MOOG

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MOOG VALVE CO., INC. PRONER AIRPORT EAST AURORA, N. Y.

Characteristic big clamshell doors of the Fairchild C-119 Flying Boxcar will soon give way to a new arrangement of double doors hinged at right angles to the clamshells. A curved section of the floor at the rear end of the fuselage can be lifted to make a huge hole through which paratroopers or bundles can be dropped. For dropping larger equipment, such as a howitzer, the entire rear section can be raised in flight, as shown in this photo. Clamshells could not be opened in flight.

being produced by the Wright Aeronautical Division and the Buick Division of General Motors Corporation, under license. . . .The Department of Defense announced on March 17 that Curtiss-Wright Corporation is participating under Air Force contract in design studies for the application of atomic power to the propulsion of aircraft.

• **Fairchild Aircraft Division of Fairchild Engine and Airplane Corporation. . .**A new rear door that can be opened and closed in flight has been designed for the C-119 Flying Boxcar, to replace the huge clamshell doors that had to be removed entirely if it was desired to drop large pieces of equipment or bulky supplies by parachute. The bottom section of the new door may be lifted while in flight, providing a large opening for paratroops to jump through or for releasing resupply bundles. It is also possible for the entire rear end of the fuselage to be raised on a hinge, providing an unobstructed opening the full height and width of the fuselage for air-dropping heavy equipment. The doors are operated by hydraulic power. More than 100 C-119's now in service will be fitted with the new flight-operable doors, the company said.

• **Fairchild Camera and Instrument Corporation. . .**Freed Electronics and Control Corporation has been acquired by Fairchild and will be operated as a subsidiary.

• **Firestone Tire & Rubber Company. . .** Extensive service testing has shown that a new nylon cord tire gives up to 20 per cent more landings than tires now used on the main wheels and nose wheels of large commercial air liners, the company announced.

• **Flight Refueling, Inc. . . .**Unusual test facilities used in developing the techniques of in-flight refueling of aircraft were demonstrated to the press recently at Friendship International Airport, Baltimore. In the "wet lab," a proving ground for the probe and drogue equipment manufactured by FRI, mating of the hoses in mid-air and unreeling of the tanker hose can be simulated, with fuel flowing through the connection at the rate of hundreds of gallons per minute. The tests are observed from an explosion-proof control room. The "dry lab" has facilities for conducting vibration, strength, and power-transmission tests under a wide range of altitude, temperature, and humidity conditions. Several of the facilities were completed recently.

• **The Garrett Corporation. . .**A $1,300,000 building for administrative and engineering offices is under construction as an extension of the plant of AiResearch Manufacturing Division, adjacent to Los Angeles International Airport. The new building will have 82,000 sq.ft. of floor space and will house 1,000 members of the AiResearch engineering department.

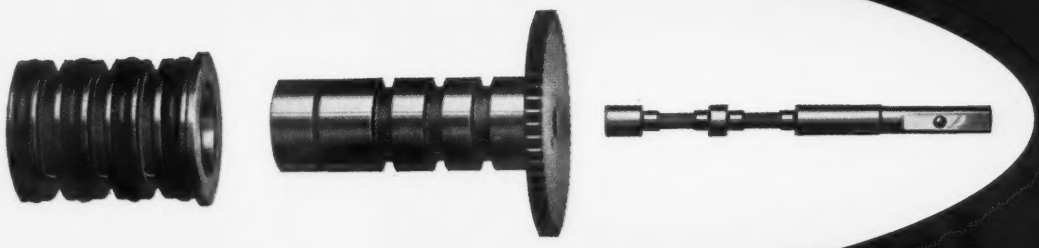
Portable arctic shelter 35 ft. by 32 ft. derives its structural strength from arched rubber tubes inflated with air. Capable of housing radar equipment and crew of 30 men, it was developed by B. F. Goodrich, Bendix Radio, and Rome Air Development Center, USAF.

• **General Electric Company. . .**Advance prototypes of exhaust gas thermocouples are offered free of charge to jet engine manufacturers in an effort to help them shorten the time between design and production. Frequently, G-E provides the tailor-made thermocouples upon 24 hours' notice. . . .A 3/4 hp. submersible pump motor, designed to operate safely while immersed in high-octane gasoline, has been announced by G-E. It fits inside a $3^1/_2$-in. gasoline pipe. . . .A new fuel pump developed by the Aircraft Accessory Turbine Department has been installed in the North American F-86D, replacing a heavier and more complex system. According to G-E, the air-turbine-driven pump can feed 86 gal. of vapor-free fuel per min. into the afterburner of the plane's J47-33 jet engine. . . .Details on the General Electric J73 turbojet engine, which is rated in the 9,000-lb. thrust class, have been released. The J73 has the so-called "cannular" type of combustion system in which a single combustion space contains ten individual "cans." Some of the accessories, housed in the nose of the J47 engine, have been placed underneath on the J73 in order to give a greater air inlet area to the 12-stage compressor. A two-stage turbine is connected directly to the compressor through a large-diameter hollow shaft. The basic engine control is a hydraulic system. Exhaust temperatures are controlled electronically during starting. The J73, which powers the North American F-86H Sabre, is 36.75 in. in diameter and 148 in. in length.

• **General Electric Company and American Airlines, Inc. . . .**When installed in 1946, the G-E generator systems on American Airlines' Douglas DC-6's and Convair 240's had an expected life of 700 hours. This has been extended to 1,400 hours on the 240's and 1,800 hours on the DC-6's. G-E engineers attributed the longer life to development of a new brush that performs equally well at high or low altitudes, to development of a shielded-type generator bearing that will rotate in its housing, and to reduction of spline wear while keeping adequate damping of torsional vibrations.

• **G. M. Giannini & Co., Inc. . . .**The new Model 47155 Pressure Transducer, designed for applications requiring an electrical output proportional to pressure, is in production. This is an improved, low-cost version of Giannini pressure transmitters that have been used for years in aircraft and missiles.

• **The B. F. Goodrich Company. . .**The first high-pressure, tubeless airplane tire capable of absorbing the severe shock of landing at 300 m.p.h. has been developed, according to a company announcement that said the tire had been repeatedly subjected to dynamometer tests representing a 10,000-lb. impact at 300 m.p.h. and the full landing run. The tubeless tire is said to be better balanced and to retain air longer than a conventional airplane tire. It is no larger than a passenger-car tire. . . . Goodrich has been granted a patent covering an inflatable rubber strip that seals



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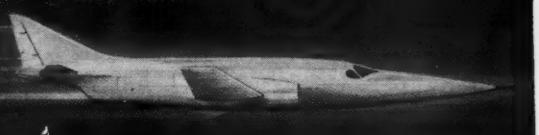

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Lockheed T2V-1, first jet trainer designed to operate from aircraft carriers and the first production airplane with wing boundary-layer control, is shown on test flight. The two-seater flies 600 m.p.h. but lands at only 97 m.p.h.—slower than any other jet. Leading-edge slats can be moved over a 17° arc. The advanced Navy trainer was designed for either the Allison J33-A-22 centrifugal-flow turbojet (6,100 lbs. thrust) or the Pratt & Whitney J48-P-8 (7,250 lbs. thrust). Rear seat is 6 in. higher than front seat.

bubble-type cockpit canopies of high-altitude military airplanes. It is intended to maintain normal air pressure in the cockpit and prevent blowouts at high altitude.

• **Walter Kidde & Company, Inc. . . .** Thermalectric Engineering Company, of Van Nuys, Calif., has been purchased by Kidde and will be operated as a division. . . . Using plastic-impregnated Fiberglas in place of wire and steel, Kidde has greatly reduced the weight of its high-pressure containers for aircraft pneumatic systems. The new Fiberglas spheres are available in volumes from 50 to 2,500 cu.in. . . .Dry air at pressures up to 3,000 lbs. per sq.in. is supplied by Kidde's new service cart, which can be wheeled up to an airplane by one man. The cart has an air compressor operated by a small gasoline engine and a wire-wound steel sphere for storing the compressed air.

• **Kollsman Instrument Corporation, Subsidiary of Standard Coil Products Company, Inc. . . .** A new counter altimeter is in production for the Navy and Douglas Aircraft Company, Inc. It registers altitude on a counter, much as an automobile speedometer shows mileage. The two-digit counter shows altitude in thousands of feet, while a single pointer makes one revolution per thousand feet on a dial graduated at 50-ft. intervals. The radical improvement is expected to contribute to flight safety, as it enables the pilot to determine his altitude at a quick glance with a high degree of accuracy.

• **Lear, Incorporated. . .** A new type of vertical gyro designed to reduce and stabilize free-drift error has been put into production at the Grand Rapids Division. Known as Series 2153, it is intended for use as a vertical reference for such gyro-stabilized equipment as remote attitude indicators, autopilots, and bombing systems.

• **The Liquidometer Corp. . . .** A direct-reading, portable test unit designed for the Air Force has been placed on the commercial market for use in the installation and maintenance of capacitor-type fuel quantity gaging systems. The Model EA-810 Test Unit permits rapid field or shop testing of fuel gage components requiring measurement of capacitance and/or insulation resistance.

• **Lockheed Aircraft Corporation. . .** First C-130A Hercules built on the production line took to the air at Marietta, Ga., on April 7. The 54-ton, turboprop cargo plane left the ground after a run of only 800 ft. Built for the Air Force, the medium combat transport has a cargo compartment longer and wider than a railway freight car. It can carry a pay load of 20 tons. Wingspread is 132 ft.; the fuselage is 95 ft. long. The Hercules is powered by four Allison T-56-A-1 gas-turbine engines geared to three-bladed Curtiss-Wright Turboelectric propellers. Together, the engines generate the equivalent of 15,000 hp. . . .Just 2 days earlier, on April 5, the first turboprop Super Constellation built for the Air Force made its maiden flight at Burbank, Calif. Capable of cruising at 440 m.p.h., this YC-121F is claimed to be the world's fastest propeller-driven transport. It can carry 106 passengers or 18 tons of cargo. Its four Pratt & Whitney T-34-P-6 engines turn three-bladed Hamilton Standard propellers. The engines generate a total of 22,800 hp. . . .A moving, mechanized flight line where T-33 jet trainers are groomed for their first flight has been installed at Palmdale. As the plane progresses down the line on a dolly, mechanics perform hydraulic checks, fuel-flow checks, engine run-ups, and other preflight work. A tractor moves the line forward at intervals.

• **Minneapolis-Honeywell Regulator Company. . .** Raytheon Manufacturing Company and Minneapolis-Honeywell have joined in an undertaking to engineer and market large, high-speed electronic data-processing systems. The jointly owned company, in which Minneapolis-Honeywell has 60 per cent interest, is named Datamatic Corporation.

• **North American Aviation, Inc. . . .** USAF announced that North American's Missile and Control Equipment Department is developing the SM-64 Navaho long-range, surface-to-surface guided missile. Details of the missile and its performance were not revealed.

• **Northrop Aircraft, Inc. . . .** The Anaheim (Calif.) Division is manufacturing ultra-high-precision glass surfaces on a production basis for Air Force and Army Ordnance projects. The optical components are used in connection with guided missile and other research and development programs under way at the Anaheim plant.

• **Nuclear Development Associates, Inc. . . .** NDA has been retained by the NACA to survey facilities within 50 miles of Cleveland in quest of a location for NACA's proposed atomic reactor, which is to be used for research on atomic power plants for aircraft.

• **Pan American World Airways, Inc. . . .** Streamlined main-wheel well doors have been designed by P.A.A. engineers for DC-3's and C-47's equipped with R-2000, R-1830, or R-1820 engines. This modification, which increases the cruising speed by 10 m.p.h., has been approved for transport category aircraft by the CAA and is available at the company's Brownsville, Tex., Customer Service Base for individual or fleet aircraft operators. These new landing gear doors are said to add only 80 lbs. weight. . . .The company has sold its 36 per cent interest in Middle East Airlines to Saeb Bey Salaam, of Lebanon, President and principal stockholder of M.E.A. Pan American has purchased the six-story Airlines Building in Beirut; it previously had a 50 per cent interest in the building.

• **Pratt & Whitney Aircraft Division. . .** The first J-57 jet engine, which was constructed as an experimental model in 1949, has been presented to the Smithsonian Institution for permanent display in the National Air Museum. The original barrel-shaped engine, called the X-176, was the first successful twin-spool jet turbine.

• **Republic Aviation Corporation. . .** Republic has designed a new ejection seat adaptable to most military aircraft and will use it in the F-84F fighter-bomber and the RF-84F. The seat is claimed to have a number of advantages for the pilot, including simplicity of operation in an emergency and a time-delay device that releases his safety belt in 2 sec., freeing him from the seat at the height of its trajectory. There are also manufacturing economies. Republic has licensed Aircraft Mechanics, Inc., of Colorado Springs, Colo., to manufacture and sell the seat. . . . The Greater New York Safety Council awarded Republic a top citation for its 1954 safety achievement. It was said that the company's 1954 lost-time accident

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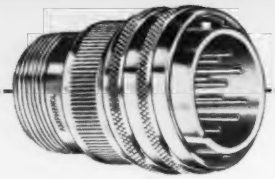

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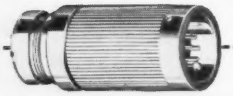

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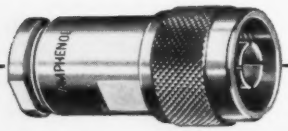

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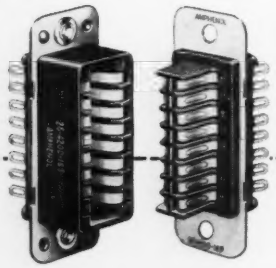

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• **Ryan Aeronautical Company. . .**Maximum speed of the Ryan Firebee jet target drone was disclosed recently as 610 m.p.h. at sea level or 605 m.p.h. at 40,000 ft. It can climb 8,500 ft. per min. The Firebee, which is 17 ft. 3 in. long, is designed to fly under remote control from the ground, after air launching from a plane, for 1 hour 20 min. at 575 m.p.h. at 40,000 ft. Potential tactical applications as a guided missile or for reconnaissance are being studied, Ryan indicated.

• **Solar Aircraft Company. . .**A $100,000 facility for testing gas-turbine engines is scheduled for completion next month. The building will contain five test cells and a 1,800-hp. diesel engine. . . .A new British corporation, Sugg Solar Ltd., has been formed to manufacture and market Solar's Mars gas-turbine engine. The new company is owned jointly by Solar and by William Sugg & Company, Ltd., England. Sugg Solar Ltd. will manufacture the gas turbines for both military and industrial uses in a new factory being constructed in Crawley, England.

• **Sperry Gyroscope Company, Division of The Sperry Corporation. . .**After extensive flight testing at WADC and Eglin AFB, the Air Research and Development Command and Sperry announced an improved system for remote control of jet fighter aircraft used for drone missions or nuclear tests. The radio-radar apparatus is said to give split-second control during all maneuvers; and if the control signals should be cut off by power failure, a device in the drone plane will fly it safely until contact can be restored. . . .Three QF-80 jet planes, fitted with the Sperry robot command guidance system, flew through an atomic blast on April 15. Two were damaged by the blast—one was crash-landed on a dry lake bed by its director aircraft, the other was lost in the mountains. The third drone landed safely. Another drone had been lost on take-off but was replaced by a stand-by.

• **Thompson Products, Inc. . . .**A new plant will be constructed in Detroit at a cost of $6,000,000, and an existing factory and office building in Cleveland will be purchased for $3,000,000 the company announced.

• **United Air Lines, Inc. . . .**UAL planes will be equipped with C-band radar beginning this fall, the company announced, to enable pilots to fly through rainstorms that are now detoured and to keep pilots informed of changing weather conditions as far as 150 miles ahead. UAL has ordered 200 air-borne radar units.

• **Vickers Incorporated, Division of The Sperry Corporation. . .**Contract has been awarded for construction of an engineering and administration building on a 76-acre site in suburban Detroit. A research and development laboratory will be included in the building, which will have 150,000 sq.ft. . . .Vickers now offers custom-made electric motor-driven hydraulic pumps with high overall efficiency and low input amperage for use as an independent, auxiliary source of power or as a primary power source in remote areas in aircraft oil-hydraulic systems. The new motor

pumps are usually rated at 3,000 lbs. per sq.in.

• **Western Gear Works.** . .The Electro Products Division has announced Bulletin 254A, which contains specifications and descriptions of more than 50 miniature motors, fans, and blowers. This new catalog may be secured by writing on company letterhead to Ronald C. Hinman, Executive Offices, Western Gear, P.O. Box 182, Lynwood, Calif. . . .Western Gear has opened an application engineering office at 1101 Vermont Avenue, Washington, D.C.

• **Westinghouse Electric Corporation.** . . The Schneider Manufacturing Corporation, of Muncie, Ind., a wholly owned subsidiary of the Westinghouse Electric Corporation, has been dissolved to form the Hydraulic Drives Department of the Westinghouse Gearing Division. The new department will engineer, manufacture, and sell hydraulic torque converters and associated brakes and transmissions. . . . A new bulletin describing the type FG 5- or 10-kw. variable frequency audio amplifier may be obtained by addressing a request for No. 85-950 to Westinghouse, P.O. Box 2099, Pittsburgh 30.

• **Wyman-Gordon Company.** . .A west coast office has been opened at 3670 Wilshire Boulevard, Los Angeles.

IAS Sections

Baltimore Section

Raymond D. Blakeslee
Secretary

The fifty-seventh meeting of the Baltimore Section was held on March 10 in Maryland Hall, The Johns Hopkins University. Seventy members and guests were present.

Herman Pusin presided. After the Secretary's report was presented, Chairman Pusin made some announcements and discussed the activities of the Baltimore Section in getting students interested in professional work. He then introduced William Street, Chairman of the Program Committee, who presented the speaker of the evening, Lt. Comdr. James L. Holbrook, USN.

Commander Holbrook spoke on "Latest Developments in Aircraft Carrier Operations." He discussed the problems of carrier-based jets, their take-off and recovery operations. He explained the limitations of hydraulic, powder, and steam catapults and discussed development of the angled deck and new barricades for halting jets that miss the arresting cables. He talked about the latest developments in landing aids and investigations of human tolerance limits.

Commander Holbrook showed a motion picture of the latest carrier aircraft operating aboard the U.S.S. "Hancock," the first vessel equipped with a steam catapult. Slides were used to illustrate new features in aircraft carrier design.

Boston Section

J. B. Tucker, *Secretary*

Colonel Bernt Balchen, USAF, noted pilot, arctic explorer, and adventurer, was the speaker at the March 23 meeting of the Boston Section. Colonel Balchen was pilot on the first flight over the South Pole with Commander Byrd in 1928 and was chief pilot of several later expeditions. He built the first major arctic airfield in south Greenland in the early years of World War II. Later, by counterespionage, he assisted in freeing his native Norway. These are but a few of the highlights of Colonel Balchen's colorful career.

In his talk, Colonel Balchen told of the early explorers and fliers who, with varying degrees of success, attempted to reach both poles. He emphasized the importance of the knowledge gained by these early expeditions to the more successful later ones, which had the advantage of better-developed equipment and techniques. The aerial conquest of the North Pole nearly simultaneously by Byrd and Amundsen did much to push back northern frontiers, he said. Air transportation made possible the settlement of northern Canada and Alaska. Even today, the airplane is the only dependable means of all-year-round transportation in these areas.

He told how these techniques were employed during World War II to ferry fighter planes to the European area. Again, these same but more highly developed techniques were employed in constructing arctic airfields and teaching survival methods to pilots downed on the icecap.

Colonel Balchen described some of the difficulties encountered while constructing an airfield on the permanently frozen ground. One time he drilled to a depth of 1,500 ft. and found the ground still frozen. This occurred while he was in command of the construction and operation of the Bluie West 8 ferry air base in south Greenland. This was a pioneer effort at building a permanent arctic air base. This air base is now an intermediate stop on the Scandinavian Airlines System transpolar flights.

He expressed the opinion that polar flights would become more commonplace as airplane range increased and as the intercontinental traffic warranted it. The most heavily populated areas of the globe are considerably north of the equator. Hence, intercontinental traffic from the northern United States to China or India would be much shorter following a great circle route over the Arctic rather than flying transversely around the world.

Colonel Balchen's talk was greeted by an enthusiastic ovation from the 106 members and guests present.

Chairman Jerger announced that Abraham Hyatt, Chief of the Research Division of the Bureau of Aeronautics, would speak at the April meeting.

Columbus Section

P. V. Titus, *Secretary*

The March 15 meeting of the Columbus Section lured 65 members and guests to the Worthington Inn for a chicken dinner. After dinner, the group motored to Don Scott Field for a tour of the Ohio State University Aeronautical Laboratory. Professor Von Eschen, Chairman of the Aeronautical Engineering Department, gave a summary of the development of this test facility since World War II.

The tour began with an inspection of the diesel-driven power plant for supplying the high-pressure air. Following a general explanation of the supersonic tunnels and their capabilities, blows were made in two of the supersonic tunnels, and the schlieren equipment was focused on a screen to show the effect of Mach Number on the shock waves as Mach Number was varied. The wind tunnels at the facility consist of:

12- by 12-in. supersonic wind tunnel. Intermittent blowdown type, open jet, Mach Number range 2.0 to 4.25.

12- by 12-in. transonic wind tunnel. Intermittent blowdown type, porous throat, Mach Number range 0 to 3.0, static pressure equal to atmospheric.

$3^1/_2$- by $5^1/_2$-in. supersonic wind tunnel. Continuous flow, closed-circuit type, Mach Number range 1.5 to 3.3.

$1^1/_2$- by $1^1/_2$-in. high-pressure facility. Nearly continuous, blowdown type, Mach Number range (with heat added) 1.0 to 10.0.

Extensive shop facilities and test instrumentation are available. Most of the contracts to date have called for studies of problems in wind-tunnel design, with model testing being confined to pressure measurements. Equipment and instrumentation for force measurements on models are being incorporated at present.

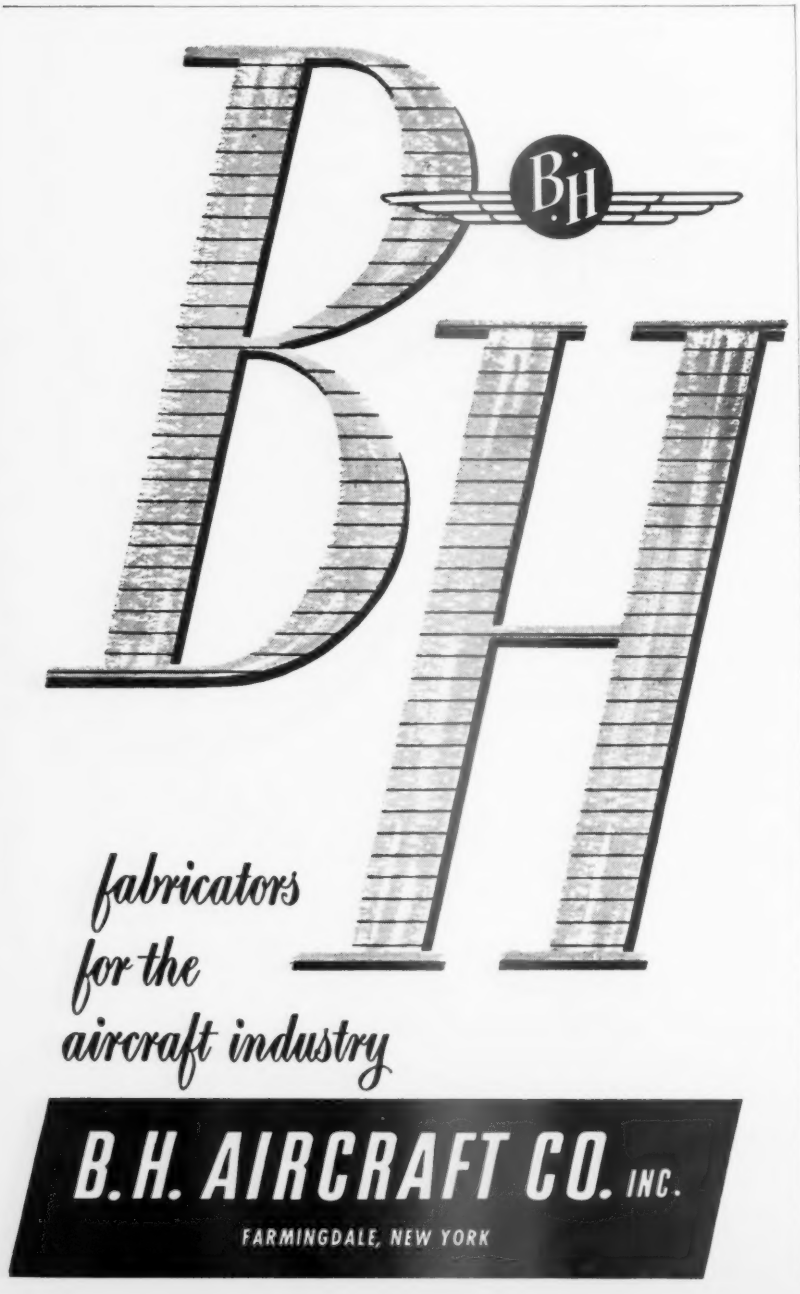
▶ The February 15 meeting of the Columbus Section was held at the Officers Club, NAS, Port Columbus, with 60 people present for dinner. Richard V. Rhode, Assistant Director for Research (Aircraft Construction), NACA, spoke on "Fatigue: Where Are We and Where Do We Go?"

Fatigue is one of today's biggest design problems, he said. The design trends toward increasing size, wing loading, speed, ratio of useful load to weight, load factor, and allowable design stress have served to shorten fatigue life considerably. Large weight-saving programs over the years have resulted in much improved structural geometry and efficiency. These factors have further reduced fatigue life. As a result, fatigue life has come down several orders of magnitude in the last 30 years.

Since it is not practical to add the structural weight necessary to achieve the desired fatigue life, Rhode said, it would seem to be of paramount importance from a flight safety standpoint that the fatigue life that exists be predictable. Fatigue life prediction on complex structures from repeated load tests is, in general, inconclusive. Structural life is dependent not only on load cycles but also on chemical action of the atmosphere and stress corrosion action. It therefore appears that the fatigue life of a structure under actual operating conditions is not predictable.

Since failures will occur, it is up to the designer to make sure that the initial failure is not catastrophic. The highest rates of catastrophic failure occur in nonredundant structures. If a structure has slow crack-progression properties and easy inspectability, most cracks can be found and stopped or parts replaced before the integrity of the structure is threatened. Mr. Rhode showed a series of slides that compared the time rates of failure of different types of structures.

Mr. Rhode has been with the NACA since 1925. He was Chief of the Aircraft Loads Division at Langley Aeronautical Laboratory prior to assuming his present duties in Washington 5 years ago. His initiation of gust research programs at Langley in 1930, and subsequent work, led to the early recognition and appreciation of the importance of fatigue in the design of aircraft structures.



▶ The fifth dinner meeting of the season was held at the Officers Club, NAS, Port Columbus, on January 18. Sixty members and guests were present. The speaker was Harold D. Hoekstra, Chief Project Officer, Aircraft Engineering Division, CAA. Mr. Hoekstra's talk might be summarized as an overall look at civil aviation as it is today, including a brief discussion of a number of important technical problems. Some of the matters discussed were air safety trends in air-line operations, safe operating conditions for helicopters, problems in putting new transport designs into service, and effects of the trend toward jet air liners on airport requirements.

▶ Peter L. Marshall, Aerodynamics Engineer, Columbus Division, North American Aviation, Inc., spoke on "Fun with Fences" at the December 7 meeting of the Columbus Section. His talk covered the wing-fence development programs conducted at North American's Columbus plant during the past year.

Mr. Marshall discussed the stalling characteristics of swept-wing aircraft and their general flight behavior at high angles of attack. He pointed out that actual stalling speeds are often misleading as a performance parameter in the high-speed designs of today. The general stability and control characteristics at high angles of attack may be so poor as to limit flight speeds to 10 or 20 knots above stall speed.

There are, of course, many means available for improving these characteristics. Leading-edge devices such as slats, fixed camber, variable camber such as a droopable leading edge, and wing boundary-layer-flow fences all work to varying degrees. While these devices improve the general flying qualities at low speeds, they are not always completely satisfactory.

Wing fences, when located properly, will usually improve the low-speed flying qualities of today's high-speed swept-wing airplanes whether they are used in conjunction with other leading-edge devices or not. Since the wing boundary

layer is considerably influenced by Reynolds Number, wind-tunnel development programs to determine best fence positions are usually not successful unless Reynolds Numbers reasonably close to the flight conditions are obtainable. Fence studies are therefore carried out as part of an airplane's flight-test program.

Movies of one of North American's recent fence programs were shown. The wings were tufted to show the effect of different fence locations on the deterioration of the boundary-layer flow as stall was approached. The art of fence location, to date, is certainly an empirical one. The fence configuration that gives that subtle blend of flying qualities the pilots will consider best can probably be obtained only through a flight-test program where the pilots can pick and choose.

Dayton Section

Gunther R. Graetzer, *Secretary*

Fifty persons attended the March 24 meeting of the Dayton Section at Cordell's Supper Club in Fairborn. John J. O'Neill, Jr., was guest speaker. O'Neill, who obtained his professional degree in Chemical Engineering in 1951 from the Missouri School of Mines, has been connected with Olin Mathieson Chemical Corporation since 1940 and is now Assistant to the General Manager of the Explosives Division. A summary of his speech "Packaged Power" is presented here.

Black powder was the first useful form of explosive energy. This was superseded in time by dynamites for blasting and smokeless powder for projectile propellants.

These materials permitted performance predictability and safety of handling. Powerful but controllable explosive energy made possible the construction of monumental projects like the Panama Canal and many of our great dams and reclamation efforts.

Progress in explosives technology has led to the recent development of RDX (cyclonite) which forms the explosive core of such useful packages of power as the "shaped charge." Shaped charges currently find extensive use in many nonmilitary applications—for example, in perforation of oil wells to activate oil-bearing strata. Similar oil-well tools are used which act as guns, expelling bullets at high velocities propelled by charges of smokeless powder.

Another interesting new package of power with wide application concerns the use of compressed air for mining coal in states where the use of explosives is limited. This tool consists of a tube 8 ft. long which is pressurized up to 12,000 lbs. per sq.in., following which

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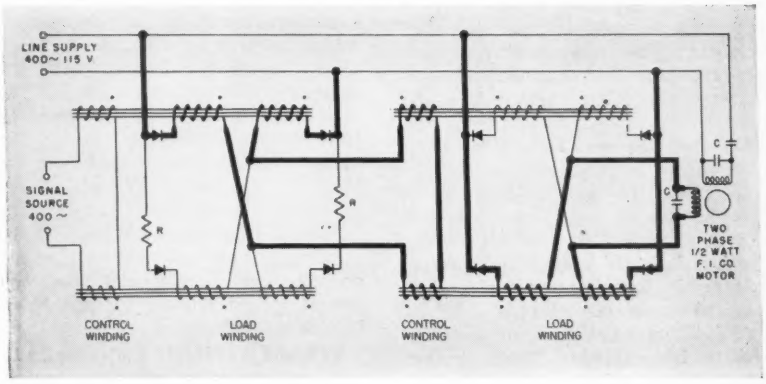
HALF-WAVE FAST RESPONSE MAGNETIC AMPLIFIER CIRCUITS

An important requisite of any practical amplifier is that it should be possible to cascade several units if more amplification is required than a single stage can offer. In usual magnetic amplifiers, this creates some practical difficulties because the inherently long time constants of each stage add up, and the cumulative time constant of the several stages may become excessive for practical applications.



Ford Instrument Company has perfected and holds the basic patents on circuits which allow cascading magnetic amplifiers with stages operating on successive half-cycles of the a-c supply.

In the circuit shown here, amplification in each stage of the amplifier is accomplished by pre-setting the core fluxes with the control-winding signal during one half-cycle of the applied load-winding voltage. During the next half-cycle, when the load-winding conducts, the control winding contribution is negligible. In this mode of operation the control winding of each stage of the amplifier receives its signal during the reset or non-conducting half-cycle of that stage of amplification. The effect of this signal occurs during the next half-cycle, thus the time constant in the stage is at a minimum of ½ cycle.

The amplifier uses half as many elements (cores and rectifiers) as the conventional bridge (full-wave circuit), and has a constantly higher figure of merit (power gain per cycle of time constant).

In amplification problems it will pay you to talk to the engineers of Ford Instrument Company. For forty years this company has specialized in designing and manufacturing special computers and controls. Send your problem to Ford.

57

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a disc is ruptured, releasing the energy confined within.

Though the foregoing represents cases where energy is packaged in a usable form, we have come to refer to packaged power devices as being principally propellants confined within a suitable cartridge and burned at a controlled and specified rate, producing energy through gasification to perform useful work.

An outstandingly successful application of such an energy source is represented by a jet-engine-starter cartridge. This device consists of approximately 4 lbs. of solid propellant, the exhaust gases from which energize a small turbine wheel connected through a gear train to the main shaft of the jet engine.

New engineering problems have arisen with the advent of high-speed aircraft which have called upon the ingenuity of propellent technologists and have resulted in another widespread application of propellant and explosive energy. These problems have arisen from the need to expel wing-tip tanks, bombs, and other external stores forcibly from the aircraft to prevent damage to the empennage. The problem here was to provide energy for ejection without damaging shock to the air frame. Further, foolproof ignition and successful operation in the conventional service-required temperature range of −70° to 165°F. with uniform operating pressures had to be realized. These ejection systems now being perfected are of special interest because the high density of energy eliminates the need to consume precious inboard space, which can be freed for other purposes.

Hagerstown Section

R. E. Eisiminger, Jr.
Vice-Chairman

The monthly meeting of the Hagerstown Section was held at the Terrace Restaurant on March 15. The meeting was brought to order by Chairman T. H. Beck, with 44 in attendance.

Mr. Beck pointed out that a program would soon be initiated to arrange talks to be given by IAS members before local junior and senior high school groups.

The program of the evening consisted of the presentation of papers dealing with the functions of the Tooling and Production Planning departments. These papers were presented by three members of the Fairchild supervisory staff: L. B. Carroll, General Supervisor of Tool Planning; D. E. Eichenbrode, Supervisor of Tool Planning; and G. W. Comstock, Assistant Superintendent of Production Planning. They were introduced by Paul Hosse. Mr. Carroll read a paper that had been prepared by C. J. Bright, Assistant Manager, Tool Engineering and Manufacturing.

Hampton Roads Section

William D. McCauley
Recording Secretary

The Hampton Roads Section held a joint meeting with the Air Force Reserve on March 2 in the Administration Building of the NACA Langley Aeronautical Laboratory. Members were urged to participate in a new program sponsored by the Section for stimulating an interest in engineering among high school students.

The speaker, Henry H. Porter, was introduced by Vice-Chairman J. D. Church to more than 160 members and guests who had come to hear about "Guided Missiles for Air Defense."

Mr. Porter has been engaged in missile research for a number of years. Since becoming associated with the Applied Physics Laboratory of The Johns Hopkins University in 1942, he has been supervisor of groups on facilities, aerodynamics, composite design and tactical analysis, and the guided-missile program. He is now Assistant Director of Planning. In these various capacities, he has directed research and development work on several guided missiles for the Navy Bureau of Ordnance.

In World War II, Mr. Porter said, a 10 per cent attrition rate for enemy bombers was considered good; today we need 100 per cent. Defense systems are being set up which are expected to destroy close to 100 per cent of the attackers or else cause the enemy to commit so many bombers or missiles to a single target that the number of targets will be small. Such a method of waging war thus becomes too costly to be practical.

This type of defense system, the speaker said, depends upon three things—detection, decision to counterattack, and destruction of the enemy force. The detection depends primarily upon our early-warning-radar net spread across Alaska, Canada, and the coasts of the United States. This radar net gives the position, speed, course, size, and type of an attacking formation. The decision to counterattack is made after this information is collected and assessed. Finally, the destruction of the enemy force depends upon two types of units: (a) those that require no flight deviation after the round is fired, such as antiaircraft; and (b) those that can account for evasive action, such as hot interceptors and guided missiles. Examples were cited showing the most effective methods of employing these units in the destruction phase and the detection time required for each. At present, enemy attackers would probably consist of bombers; in the future, we shall need to intercept supersonic and ballistic types of missiles.

The talk was concluded with a movie on guided missiles.

Indianapolis Section

Paul F. Ferreira, Jr., *Secretary*

The members of the Indianapolis Section were guests of the IAS Student Branch at Purdue University on March 8. Open House was held from 3:00 to 5:00 p.m. at the Purdue Aero School. Dinner was served in the Purdue Memorial Union Building. In attendance were 200 members, student members, and guests.

A brief business meeting preceded the evening's program. At this time, the new Student Branch officers, the Chairman of the Indianapolis Section, and the heads of the Aero School and Air Transportation School were introduced. An award was presented to the outstanding senior aeronautical engineering student at Purdue.

The speaker was H. A. Rieke, Staff Engineer, Flight Test Operations, Boeing Airplane Company, whose topic was "The 707 Jet Transport." His talk covered the progress and problems solved in the accelerated 50-hour flight test of the first 707 transport, powered by four pod-mounted J57 turbojet engines.

Mr. Rieke's talk was supplemented by slides and by a short color movie showing flight-test operations connected with the 707.

Los Angeles Section

Joseph W. Wechsler, *Secretary*

At its March 17 dinner meeting, the Los Angeles Section was honored to have as its principal speaker Robert E. Gross, IAS President for 1955 and President and Chairman of the Board of Lockheed Aircraft Corporation. Mr. Gross, whose talk entitled "Engineering—General Management: Their Roles in Our Changing Industry" was attended by a capacity audience of 500, was introduced by Guest Chairman Arthur E. Raymond, Vice-President—Engineering, of Douglas Aircraft Company. Among the other guests were Brig. Gen. J. Stanley Holtoner, Commander, Air Force Flight Test Center, Edwards AFB, Calif., and Dan Kimball, President of Aerojet-General Corporation, Azusa, Calif., and former Assistant Secretary of the Navy. Presiding at the meeting was Warren Dickinson, Section Chairman.

Mr. Gross established the frame of reference for his talk by discussing the basic changes in organic structure which

Demonstrated Strength of H-21C confirms dependability of parts made from nickel alloyed steels. This helicopter can transport 20 men, 12 litter patients plus attendants, or two tons of cargo. Produced by Piasecki Helicopter Corp., Morton, Pa.

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Performance won this craft an apt name: Work Horse. Yet it is not heavy. Weight is saved, without sacrificing safety. By using nickel alloy steel rotor hubs, drive shafts and similar vital parts.

Take transmission and pinion gears, for example. Hard, wear-resistant cases, supported by strong, tough cores, are obtained from Type 9310 steel (3¼% nickel-1¼% chromium-¼% molybdenum) carburized.

And a nickel-chromium-molybdenum steel, Type 4340, showing 180,000 psi minimum tensile strength, is used for 90 per cent of the forgings. This type is also used for scores of parts turned out from bar stock.

Bolts are of Types 4340, 8735 and 2330 nickel alloyed steels, heat treated to provide 125,000 psi minimum tensile strength, along with high toughness.

Piasecki uses several chromium-nickel stainless steels, too. Types 301, 302, 304 and 321. They go into fire walls, oil tanks, exhaust collectors, external cables and the like. These combat heat and cold, as well as corrosion.

You'll also find nickel alloyed steels used in the engines that power these "choppers." For crankshafts, connecting rods, gears, bolts and studs.

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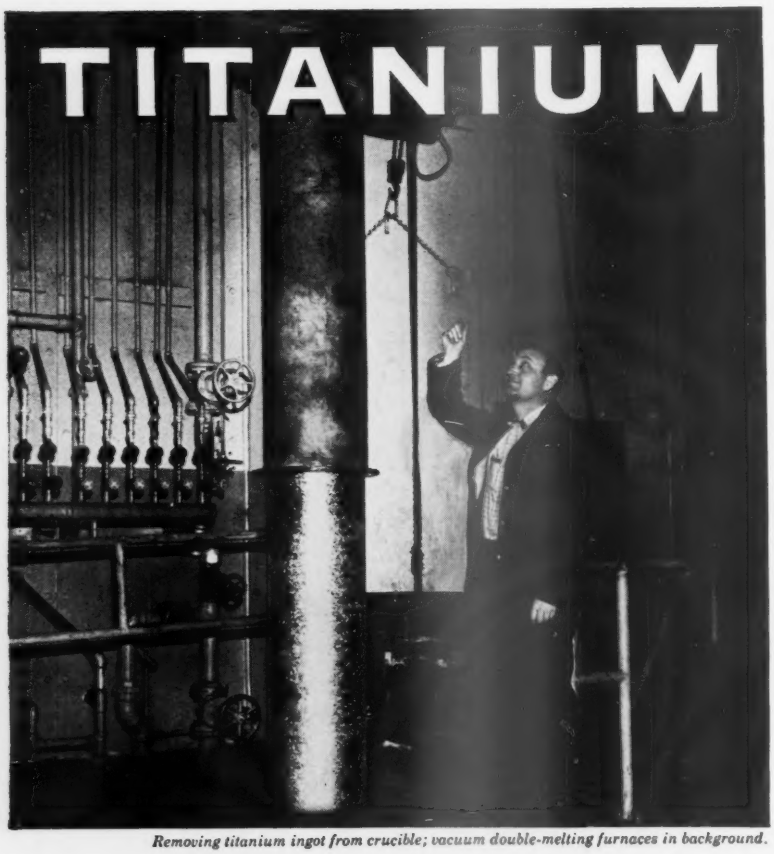

Removing titanium ingot from crucible; vacuum double-melting furnaces in background.

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the aircraft industry is undergoing. Up to 15 or 20 years ago, the air-frame and engine companies did almost all of the actual work of building airplanes and therefore controlled the design philosophy. During the intervening period, the nature of the product and its relative importance to other components of the system in which it is used have undergone such basic changes that companies with other primary interests have been getting into the aviation business, and the aircraft companies themselves are changing considerably. The major factors causing these changes in the structure of the industry have been the technological advances brought on by World War II and Korea, the dependence of the industry's fortunes on the international situation by virtue of the dominating and vigorous foreign policy of the United States in the post-war period, and the evolution of the weapons system concept. Under the weapons system concept, propulsion, guidance, and other system components require just as much development effort as the air frame, and all of them must be compatible. Hence the airplane—once the "star"—is now a contributory piece in the entire picture.

This point led logically to the role of management in the changing industry. Management's objective, Mr. Gross asserted, should be that the development of airplanes and missiles remain the province of the companies that comprise the hard core of the aircraft industry. This can be accomplished if the air-frame manufacturers undertake the systems projects themselves rather than let them go by default to other companies (In this connection, the speaker took occasion to compliment those companies that have elected to undertake systems projects.)

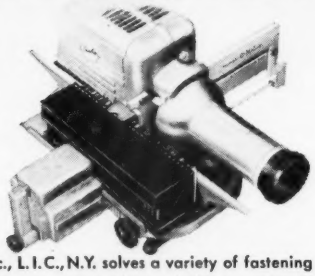
Another phase of management's role will be an awareness, and consequent exploitation, of the future sources of financial support for the aircraft industry. Two main sources are emerging for the foreseeable future. On one hand are aerial weapons, which will be the object of defense spending at a rate that will increase for some years to come and may then be expected to decline. On the other hand are air carriers, which will continue to provide a reasonably constant volume of business for many years to come.

Viewing the engineer as a partner of management—indeed, as the backbone of the industry—in this process of evolution, Mr. Gross went on to outline some accomplishments that he recommended engineers regard as their aims for the future. These recommended aims included:

(1) Drag reduction at high speeds through the successful application of boundary-layer control.

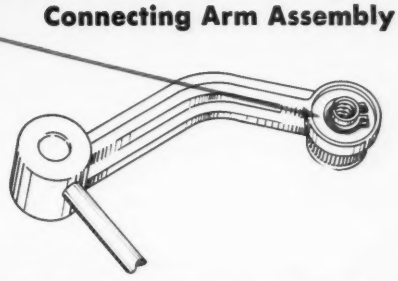
Waldes Truarc Rings Permit Better and More Economical Design—Fewer Parts, Faster Assembly, Minimal Rejects!

Viewlex's Change-O-Matic



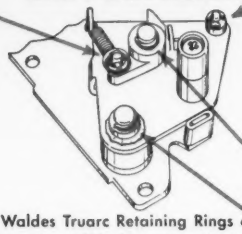
Viewlex, Inc., L. I. C., N.Y. solves a variety of fastening problems in their new model Change-O-Matic automatic slide changer. Assembly time is speeded, parts eliminated, rejects lowered, and compact, economical product design achieved.

Connecting Arm Assembly



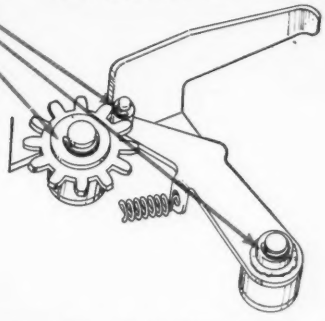
Use of one Waldes Truarc Ring (Series 5100) eliminates time-consuming riveting over the flange, retains and holds the connecting knob captive. A compact, neat design is made possible, rejects caused by poor riveting eliminated.

Actuating Plate and Pawl Assembly



Three types of Waldes Truarc Retaining Rings are used in this assembly. One circular self-locking ring (Series 5105) retains pawl return spring. One external E-ring (Series 5133) retains roller used to prevent gear motion during transport cycle. One crescent ring (Series 5103) retains pawl which indexes gear. Second crescent ring retains sub-assembly. Truarc Rings speed assembly, cut rejects, eliminate parts.

Dentent Lever Assembly



Truarc E-ring (Series 5133) eliminates use of tapped hole and shoulder screw, retains roller which prevents over-travel of gear. Assembly is rapid.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product... to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

36 functionally different types... as many as 97 different sizes within a type... 5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U. S. A. and Canada.

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(2) Reduction of the effects of clear-air turbulence, especially at high speeds and altitudes.

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(4) More complete families of engines from which airplane designers can choose—e.g., turbojets with thrust ratings at 1,000-lb. intervals and turboprops with power ratings at 1,000-hp. intervals.

(5) Lightweight shielding for crews of nuclear-powered airplanes.

(6) Development of computing methods to give theoretical answers on new designs quickly; specifically, the ability to determine an optimum configuration, by varying numerous input parameters, in less than 1 day.

In conclusion, Mr. Gross brought together the roles of engineering and management by urging the development of what he termed the "engineering-manager type of person." By becoming inculcated with the qualities of mind and attitude which make the sober man, the engineer will avoid becoming so specialized that he loses his perspective of the humanities and will encompass the broad aspects of a full life. Such a development would solve the problem, so often encountered, in which the only means of rewarding a good engineer is to take him out of a creative environment, where he is at his best, and put him in a managerial position for which he may not be qualified. This would also help to bring man's spiritual achievements more nearly abreast of his technical advances. In so doing, it would be an accomplishment in the field of Man, which after all is the greatest work of all.

▶ Two hundred members of the Los Angeles Section, drawn by lot, spent March 10 aboard the aircraft carrier U.S.S. "Hancock" as guests of Vice-Admiral Harold M. Martin, COMAIR-PAC. After being welcomed aboard by Captain Eddie R. Sanders and Commander Philmore B. Gilkeson, the ship's Executive Officer, the visitors were divided into groups of ten to facilitate inspection of the various facilities on board by some of the groups, while others witnessed flight operations from the island superstructure.

As a result of inclement weather, jet operations had to be cancelled for the day, and the only aircraft in operation were the twin-engined Grumman S2F-1's. However, the ease with which these large airplanes were launched by the steam catapults and retrieved by the latest-model arresting gear proved to be extremely interesting. The tours of the ship's facilities, skillfully planned by Public Information Officer Lt. (j.g.) R. K. Parmacek to avoid traffic jams in the cramped quarters, included such points as the boiler and turbine areas, steam catapult mechanisms, ship's control room, hangar deck, mess facilities, crew's quarters, and ship's hospital.

Traditional Navy hospitality, extended by every member of the ship's company, rounded out a pleasant and informative experience.

Ellis Lapin
Member, Field Trips Committee

On Tuesday evening, April 5, approximately 55 members of the Los Angeles Section were guests of the Bethlehem Steel Company on a tour of inspection of its Vernon, Calif., plant. The plant is a fully integrated steel mill operation, with the exception of blast furnaces, and the complete steel manufacturing process was on view. The processes witnessed included the reduction of scrap to ingots for the use of electric arc furnaces, the production of structural forms in rolling mills, the operation of various reheating furnaces, and the manufacture of bolts and similar items from rolled stock by means of special machinery.

▶ More than 150 members attended a confidential specialist meeting addressed by Emmet A. Mossman, Aeronautical Research Scientist, Ames Aeronautical Laboratory, NACA, on March 21.

Jerome L. Fox
Member, Specialist Meetings Committee

W. W. Kellogg, Head of the Geophysics Group of The RAND Corporation, was the speaker at a specialist meeting of the Los Angeles Section held on March 8. His timely topic, "Probing the Weather Above 100,000 Feet," drew an audience of 85.

Kellogg first described the methods for deducing temperatures at extreme altitudes which were used before the advent of sounding rockets in 1947. These included observations of aurora, noctilucent clouds, width of emission lines of atomic oxygen, and reflection of radio waves from ionized layers. He then pointed out that these estimates proved to be in remarkable agreement with subsequent direct measurements by rockets. In conclusion, he discussed the present state of knowledge of winds at extreme altitudes and pointed out the need for more intensive investigation of this subject.

Donald Coles
Member, Specialist Meetings Committee

At a specialist meeting of the Los Angeles Section held on February 22, Mrs. Rose Marie Licher of the Santa Monica Division of Douglas Aircraft Company, Inc., spoke on "Reduction of Drag Due to Lift and Thickness in Supersonic Flow." Attendance was 57.

Using the theory of linearized supersonic flow, Mrs. Licher showed the possibility of combining thickness and camber in two-dimensional multiplane wings so as to reduce the total wave drag for a given lift. She also applied some general theorems of W. D. Hayes, R. T. Jones, and E. W. Graham to three-dimensional configurations to illustrate possible techniques of optimization when drag arises from both lift and thickness, or when lift is distributed between fuselage and wings.

Niagara Frontier Section

Clifford L. Muzzey, *Secretary*

On March 9, the Niagara Frontier Section was honored to have as its speaker Lt. Gen. W. E. Kepner, USAF (Ret.), Executive Vice-President, Bell Aircraft Corporation. The dinner meeting at the Park Lane Restaurant was attended by more than 100 members and guests. James O'Malley was Program Chairman.

General Kepner was introduced by his colleague, Roy Sandstrom, Vice-President of Engineering at Bell. During his military career, the General saw service with Army, Navy, Marine Corps, and Air Force. His early aviation experience was with lighter-than-air equipment in which he qualified as both balloon and Zeppelin pilot. In World War II he commanded the 8th Air Force and later the 9th and took part in 14 bombing missions and 10 fighter missions.

General Kepner has been witness to the evolution of air power, and he recounted his part in the great development from its uncertain status of the 1920's, through General Andrews' struggle to get the B-17 aircraft, and the tremendous job of engineering, production, and utilization of the World War II period, to its present advanced position as a science. He paid tribute to the men who guided and contributed to the evolution—the well-known names of Andrews, Mitchell, Arnold, LeMay, and the unknown thousands of men who added their share, whether in the last few minutes of a bombing run when the bomber could not take evasive action, or in a laboratory.

The General looks to men of the present day and the future to press forward with new developments and scientific achievements such as the vertical-take-off planes and rocket flight, both earth-bound and in outer space. These will be the next steps in the scientific evolution of air power, he believes.

General Kepner summed up science with the definition given him as a boy by a Dakota ranch hand. "Science,"

NOW ...rated at 500°F!

Another advance in lightweight flexible hose assemblies

Constant hose development work at Resistoflex has paid off again. Service experience has permitted an improvement in temperature rating of Fluoroflex*-T R-500 hose... the first aircraft hose to use Teflon* . . . the first to warrant a 500°F rating at 1000 psi (750 psi in the larger sizes).

Made with Fluoroflex-T (Teflon-compound) tube, SAE 304 stainless steel reinforcing braid and blowout-proof compression fittings, the lines offer *permanent* plumbing . . . no swelling, no erosion, no aging. Their flexibility stays the same throughout the temperature range. Fluoroflex-T R-3800 hose assemblies are A-N approved for use with synthetic oils, fuels, and fuming nitric acid

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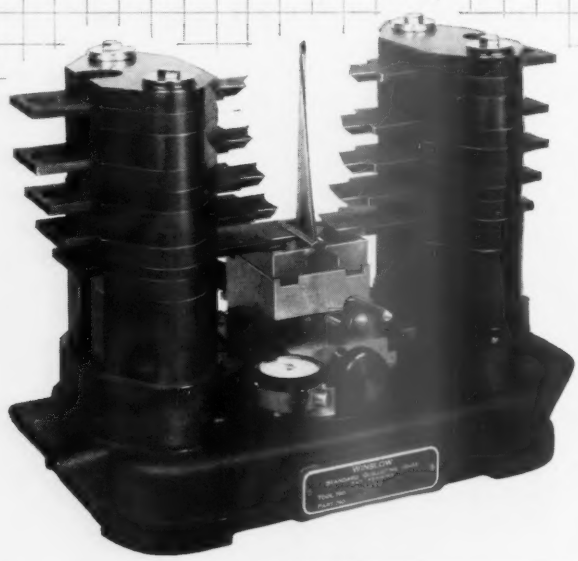

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Already in use by the leaders of the jet engine industry, this new kind of guillotine gage solves the problem of maintaining accuracy. Templates are supported over a much larger area of their surface, making wear negligible. And alignment is guaranteed by heavy stacked towers that are bolted together for ruggedness and complete rigidity. Winslow's new design and assembly from precision-built interchangeable parts give six big advantages. You get quick delivery and lower original cost. You save on maintenance—in case of damage substitution of some parts can be made without even removing the gage from your inspection line.

Gage down-time is cut, requiring fewer gages and avoiding costly production holdups. And finally, you reduce your gage investment with a truly multi-purpose instrument—check all 10 features of a jet engine blade with a single gage; check forging and finished part with only one gage. No more gage obsolescence—Winslow's Re-Work Service quickly up-dates the gage when your part changes. Easy to use and easy to read, the Winslow speeds production, gives "more accuracy for less money."

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said the philosopher, "is a man's limit to the understanding of God's perfect laws."

San Diego Section

D. P. Germeraad
Acting Corresponding Secretary

An audience of 200 heard Lt. Col. Frank K. (Pete) Everest, Jr., speak on "Flight Testing from the Pilot's Viewpoint" at the March 31 meeting of the San Diego Section. As material for his talk, Colonel Everest called upon his vast store of professional flight-test experience in flying the latest production and experimental Air Force aircraft. He is Chief of the Flight Test Operations Laboratory, Air Force Flight Test Center, Edwards AFB, Calif.

▶ On March 17, more than 250 members listened attentively as Krafft A. Ehricke, Design Specialist, Convair (San Diego) Division, outlined clearly and concisely "Space Flight Problems." Mr. Ehricke's thorough survey delved into the various phases leading toward interplanetary flight and their associated problem areas.

▶ At a dinner meeting of the San Diego Section on February 24, Royal Weller, Chief Scientist, U.S. Naval Air Missile Test Center, Point Mugu, Calif., delivered an excellent paper on "The Evaluation of Military Equipment." His discussion dealt in particular with testing and evaluation in the field of missiles. Seventy members and guests attended.

▶ "Design Benefits from Application of Process Controls" was the subject of a talk by Ralph Van Deventer, Vice-President, Alloy Engineering and Casting Company, on February 10. With the aid of well-defined illustrations, he covered examples of wrought and cast components, both ferrous and nonferrous, in which suitable process controls have helped designers obtain higher working stress levels and longer life.

▶ Donald D. Wall, of the Applied Science Division, International Business Machines Corporation, spoke on "The Use of Digital Automatic Computers in Industry" on February 1. After outlining historical development, he discussed the application of the digital computer to the aircraft industry in particular.

San Francisco Section

Commander Edward A. Quarterman has been elected Chairman of the San Francisco Section. The other new officers are Lester G. Kelso, Vice-Chairman; George Cooper, Secretary; and Frederic E. Titus, Treasurer.

Washington Section

R. Fabian Goranson, *Secretary*

On April 8, the Washington Section held its meeting at The Glenn L. Martin Company plant in Baltimore, where members were given an opportunity to observe modern aircraft production methods during an inspection of the P5M assembly lines and the shops where aircraft parts were being made. The tour of the Martin facilities was concluded by an engine run-up of a B-61 "Matador" pilotless bombardment vehicle.

Following dinner, Boyd K. Bucey, Manager, Tool Design, Boeing Airplane Company, presented an excellent paper entitled "Modern Aircraft Production Methods." Perhaps the most startling revelation of his talk, at least to those not familiar with production problems and techniques, was the extent of cooperative efforts among aircraft companies toward development of uniform and efficient production techniques and the free exchange of production know-how. In fact, Mr. Bucey's talk was indeed a review of production methods in the aircraft industry as a whole rather than of methods used by the Boeing Company.

Mr. Bucey discussed in detail the basic production operations, the problems involved, and progress made in handling materials. Specifically, he reviewed methods for cutting metal sheets, forming techniques, composite skin construction by automatic riveting, welding or metal bonding, machining processes, and, in conclusion, reviewed the advancement made in tooling through the use of optical techniques for aligning jigs and the use of modern materials such as concrete, aluminum castings, and cast or laminated plastics for production jigs.

Mr. Bucey showed clearly the basic theme of his talk—that there was an unpublicized but important process in the aircraft industry which permitted the exchange of tremendous quantities of information, with the net result that most airplane manufacturing processes were the same but the end products of each company were different; furthermore, the successful production of any particular company's product depends mostly on the attitude of the working crews rather than on the machinery available for production. The proper attitude among workers is best established by bringing all people (design, production, and research men) together at an early stage in the project so that the best ideas of all can be incorporated and each, in turn, feels that he is a real part of the project. It was the consensus of the audience that Mr. Bucey had shown that the manufacturing divisions of the aircraft companies well recognize their responsibilities and are going about solving their problems in a rational and cooperative manner.

▶ On March 9, the Washington Section met in the International Room of the Occidental Restaurant to hear a report on "New NACA Wind Tunnels—Tools for Developing Supersonic Airpower."

The Honorary Chairman, Hugh L. Dryden, Director of the NACA, introduced the three speakers, each of whom described in detail the wind-tunnel facility located at one of the three NACA laboratories. Mr. Dryden also presented some background information on the development of the "unitary plan," noting that early independent studies made by the military services and the NACA had called for test centers with a combined cost of over two billion dollars. It was the obvious need to coordinate these proposals which led to the eventual appropriation of funds for three tunnels to be operated by the NACA and two by the Air Force at the Atomic Energy Development Command.

The three NACA tunnels were designed to meet the specific needs of supersonic missile development, supersonic airplane development, and propulsion research, where the AEDC tunnels were intended for full-scale engine testing and for hypersonic missile development. Mr. Dryden showed the urgent need for these facilities by means of a graph that presented the change in airplane speed records and maximum wind-tunnel speeds with time. He reported that the three NACA unitary wind tunnels were built at a total cost of $75,000,000 and required 4 to 5 years for construction. Almost 10 years elapsed from the time when the planning was begun.

Herbert A. Wilson, Jr., presented a paper entitled "Langley 4-Ft. Unitary Plan Wind Tunnel," written by himself, Isidore G. Recant, and O. Glenn Morris. The paper reported on the development, construction features, and performance capability of the facility at the Langley Aeronautical Laboratory.

E. O. Pearson, NACA Headquarters, presented a similar report on the "Ames 8-Ft. Unitary Plan Wind Tunnel." This paper had been prepared by J. L. Jones and R. F. Huntsberger.

The third paper was prepared and presented by E. W. Wasielewski, of the Lewis Flight Propulsion Laboratory. He described the unique characteristics and requirements of the Lewis 10-ft. unitary plan wind tunnel, which will be used for propulsion research.

▶ On February 8, the Washington Section held a joint meeting with the Baltimore and Hagerstown Sections to hear a program on the theme "Water-Based Aircraft." The entire program, dinner, and social hour were held at the new Johns Hopkins University Applied Physics Laboratory near Scaggsville, Md., and the host section found itself outnumbered by its guests. Of a total of 211 people, approximately 100 came from Baltimore, 75 from Washington, and the remainder from Hagerstown.

The Honorary Chairman for the evening was Rear Adm. Lloyd Harrison, USN, Deputy and Assistant Chief of the Bureau of Aeronautics. His long association with the development of water-based aircraft provided continuity as well as interesting background material for the three speakers.

F. W. Locke, Research Division, Bureau of Aeronautics, reviewed, through the medium of a series of interesting movie records, the development and testing of hydroskis. This presentation showed graphically the many promising features of hydroski-type aircraft, as well as some of the limitations.

C. T. Ray presented an equally well documented story on the "Developments in Hull-Type Seaplanes." He showed the improvements that had been accomplished through the use of increased length-beam ratios and the changes in both the forebody and afterbody bottom shape. He concluded his discussion with a short movie taken during the initial "roll out" of the XP6M-1 Sea Master to illustrate what the new breed of water-based aircraft might be expected to look like.

While the first two speakers had restricted themselves to discussions of actual developments in water-based aircraft, E. G. Stout, of Convair (San Diego), delved into the possibility of future applications under the heading of "The General Philosophy and Future Prospects of Water-Based Aircraft." By means of sketches, he showed how isolated or dispersed beaches could be used to set up advance bases. Large hull-type logistic support airplanes would be used to bring out materiel and personnel to operate these "portable" bases for hydroski fighters. To illustrate the practical thinking behind the futuristic plans, Mr. Stout also concluded his talk with a movie showing the loading of a Convair R3Y Tradewind with combat troops and equipment, its flight to an isolated beach, and finally the landing of troops with their equipment to establish a beachhead.

▶ On January 11, the Washington Section met at the Occidental Restaurant to hear a talk by Gen. James M. Gavin, Assistant Chief of Staff, Operations, U.S. Army, on "Air Mobility in the Army."

Honorary Chairman for the evening was Earl D. Johnson, then President of the Air Transport Association of America, who had been associated with General Gavin while Assistant Secretary of the Army for Manpower and Reserve Forces.

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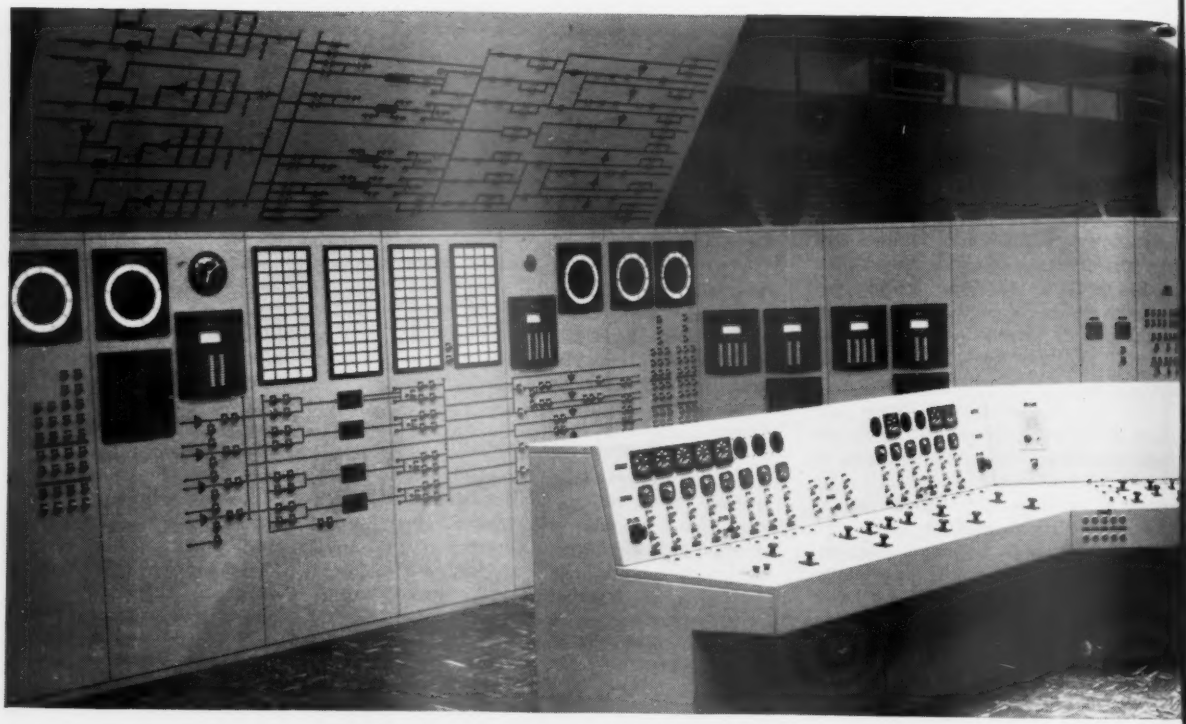

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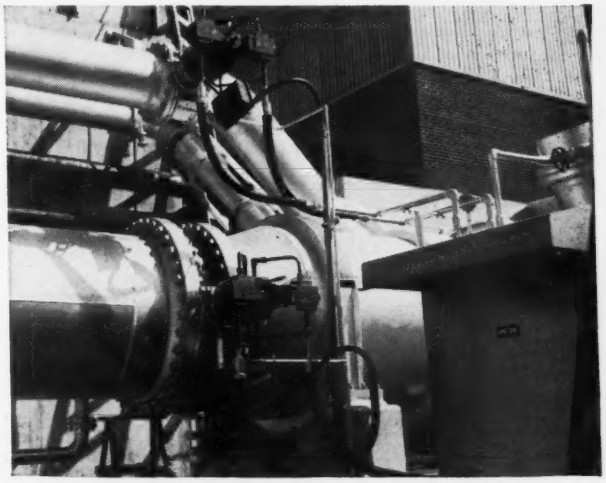
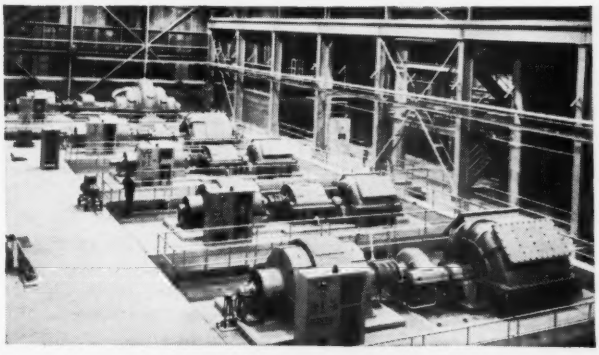
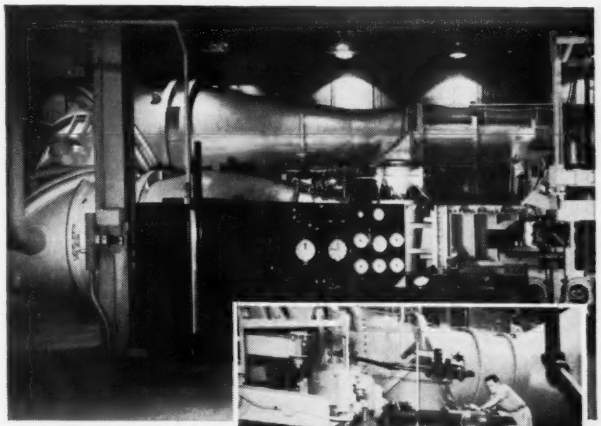


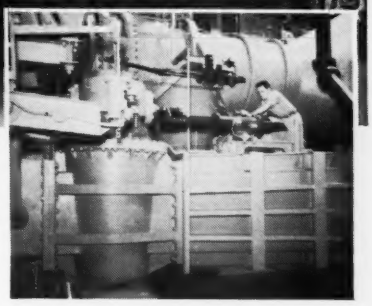
Hagan electro-hydraulic valve operators for engine test facilities



Centrifugal exhausters with Hagan surge control for engine test facility



Hagan control center for wind tunnel



Hagan pneumatic operators for wind tunnel valves

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General Gavin opened his talk with a brief historical review of successes and failures in war and showed how history had been made by nations whose defensive or offensive forces were mobile. With this background, he went on to discuss some of the problems that had been created during the latter part of World War II and during the Korean conflict as a result of inadequate planning for coordinated mobility of all services. He specifically showed the need to stress the development of adequate coordinated air transport.

Student Branches

Boston University

Courtland B. Converse
Secretary-Treasurer

The Boston University Student Branch met at the Logan International Airport division of the University on February 28, with 35 present. The speaker was George F. MacDougall, Jr., of Langley Aeronautical Laboratory, NACA, an alumnus of Boston University, who spoke on the NACA's research functions. His main purpose in coming to Boston University was to interview juniors for possible summer jobs at the NACA laboratory.

After a bit of general background, Mr. MacDougall centered his talk on the NACA's spin tunnel. This is a vertical cylinder 20 ft. in diameter, with a large fan at the top to provide a rising stream of air. The air speed can be controlled so as to make an airplane model spin freely for some time in the middle of the tunnel. Nets at the bottom catch the model when the test is completed, and nets at the top prevent it from striking the fan.

Mr. MacDougall exhibited a dynamic flying model that had been tested in the spin tunnel. Plastic models, he said, are easier to make and less likely to be damaged than balsa-wood models. A spring-loaded device, actuated by a magnetic field, moves the rudder and elevator so that observers can watch the the freely spinning model plane recover from a spin or fail to recover.

Data are recorded at the spin tunnel in the form of motion pictures, which show how quickly the dynamic model representing an actual airplane can recover from a spin. Mr. MacDougall exhibited movies of several spin tests, and spoke of spin parachutes and other devices used to bring an airplane out of a spin. One movie showed how a pod containing the pilot might be jettisoned with a parachute attached.

The Pennsylvania State University

E. Allen Weber, *Secretary*

Fifty members attended the March 30 meeting of the Pennsylvania State University Student Branch. Ralph Straley presided.

Mr. Mathieu, one of the instructors in the Aero Department, talked about the functions and purpose of the Engineering Open House and urged the students to take part in operating the wind tunnel, water table, or structures laboratory, or in explaining the airplane design projects to the visitors.

The speaker for the meeting was Mr. McCloskey from the NACA. He discussed some of the projects in progress and told us of the research facilities available at Langley Aeronautical Laboratory.

He also showed three films. The first was concerned with airflow around streamlined and blunt bodies, the effect of protruding rivets on the flow, and boundary-layer control with suction. The second film was about shock-wave formation in a supersonic wind tunnel, while the third consisted of pictures of new experimental aircraft.

▶ Thirty-five attended the March 10 meeting of the Pennsylvania State University Student Branch, with Ralph Straley presiding.

Mr. Hockman, an Aerodynamicist from North American Aviation, Columbus, Ohio, gave an interesting lecture and showed two films. He compared the power required and the power available for flight with subsonic, transonic, and supersonic airplanes and the rate-of-climb and time-to-climb variation with different Mach Numbers. Then he told how the speed is limited by both the turbine temperature of the engine and the air friction. He stressed the importance of fineness ratio of the fuselage and drag on the airplane, wing shape, and sweep. How the wing area is selected was discussed, too, as was boundary-layer control over the wings.

Two films, *This is Airpower* and *Canted Deck Tests on an Aircraft Carrier*, were then shown.

Purdue University

John F. Andrews, *Secretary*

H. A. Rieke of the Boeing Airplane Company, Seattle, spoke to a gathering of 173 students and professional engineers on March 8, when the Purdue Student Branch was host to the Indianapolis Section of the IAS at the spring banquet held in the Purdue Memorial Union Building. Most of the professional men came from industries in and around Indianapolis.

Speaking on "The 707 Jet Transport," Mr. Rieke described its interesting engineering features and some of the troubles encountered in development of the plane. His talk was illustrated with slides and a film.

The Aeronautics School held open house in the late afternoon, preceding the banquet. Student members of IAS conducted the guests on a tour of school facilities.

The annual award for the senior with the highest index in the Aeronautics School was presented to John M. Kellam. He had a 5.9 out of a possible 6.0 index for seven complete semesters.

San Diego State College

Bob Parker, *Secretary-Treasurer*

The first official meeting of the San Diego State College Student Branch of the IAS was held on March 22, at which time the by-laws of the Branch were adopted. The newly elected Chairman, Donald Hall, Jr., presided at the meeting. Ralph Gibson was elected Vice-Chairman and Bob Parker, Secretary-Treasurer. Charles Morgan, Assistant Professor of Engineering, was named Honorary Chairman.

After the business matters had been resolved, a film of the latest flight test of the Convair F-102 interceptor was shown. The film inspired a proposal that a tour through the Convair plant be arranged in the near future.

Two earlier "get acquainted" meetings really started the Branch off on the right aeronautical foot with an excellent talk by William Immenschuh, Aeronautical Engineer at the Ryan Aeronautical Company, who extended a warm welcome on behalf of the local Section of the IAS and an invitation to all of the Institute's functions. Mr. Immenschuh also gave a complete historical, organizational, and functional description of the national organization and answered many questions raised by the members.

The second of these meetings proved to be one of the most interesting that this Branch could hope to have for some time. There was an outstanding presentation by Don Germeraad, Chief Test Engineer of the Convair plant here, which included color slides of the Convair R3Y cargo seaplane and the turboprop engine that this aircraft utilizes with remarkable results.

The future activities and potential of this new Student Branch seem unlimited here in this aviation-minded city. An enthusiastic membership seems to guarantee that there will be many hours of real engineering fellowship and interesting experiences.

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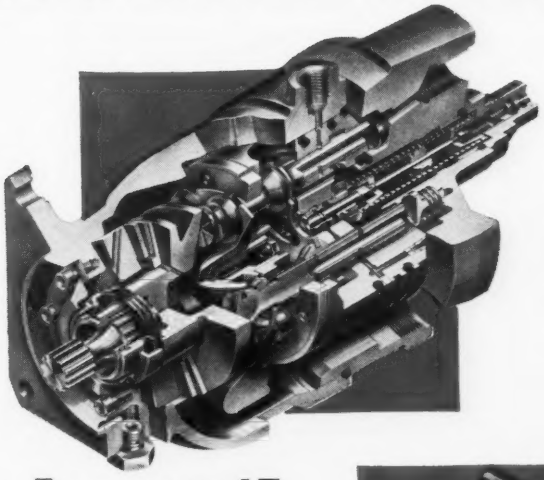

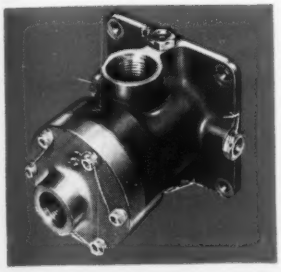

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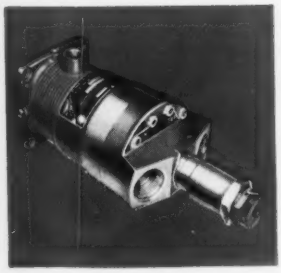

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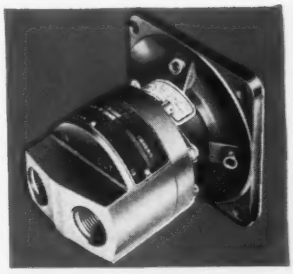

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Syracuse University

James R. Belknap, *Secretary*

Chairman Graham Ireland called to order the March 24 meeting of the Student Branch of Syracuse University. Twenty members and Faculty Adviser Joseph Cady were present. Robert Goldin, of the Structures Section, Bell Aircraft Corporation, lectured on the design program for a new airplane, describing how the work of each section of the company is coordinated. He showed films of Bell's X-1 and X-1A rocket planes and Bell's experimental VTO jet plane.

▶ Faculty Adviser Martin Barzelay attended the March 14 meeting. The speaker was Mr. Hoffman, of North American Aviation, Inc., who talked on "Problems of Flight Testing and Engineering." Mr. Hoffman told of problems encountered in designing stall fences for the Navy's FJ-4 Fury. Films were shown describing carrier operations and North American's guided-missile program.

U.S. Naval Postgraduate School

Richard J. Peterson
Corresponding Secretary

The Student Branch met jointly with Naval Reserve Research Company 22 on March 23 to hear John W. Miles, Professor of Engineering, University of California at Los Angeles, and consultant to the Ramo-Wooldridge Corporation. He spoke on "Aerodynamic Instability of Thin Shells."

Mr. Miles' discussion was devoted mainly to panel flutter, which was first observed at Peenemunde during the development of the V-2 rocket and is considered a general problem of very-high-speed flight. This phenomenon is completely analogous to the generation of water waves, with the curved-skin properties substituting for the effect of gravity and the aerodynamic load for the disturbing force in the analogy. Miles has developed his analysis on this basis and has expressed the results in the form of a minimum thickness-radius of curvature ratio required for aerodynamic stability at a given Mach Number. A conservative value of this ratio is approximately $0.007\ (M-1)^2$ for an aluminum skin.

University of Alabama

Anthony D. Gregoire, *Secretary*

An "Engineering Day" has been proposed by the Student Engineering Joint Council, and the Alabama Student Branch intends to participate. Plans call for a championship baseball game among the engineering societies on the campus and a dance in the evening.

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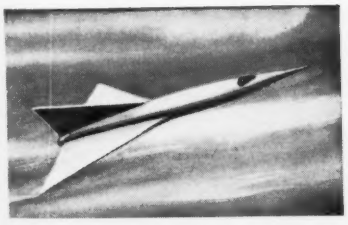

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The IAS Branch has approved plans for a picnic with the Student Branch of the American Society of Mechanical Engineers. A field trip to the Lockheed Aircraft plant in Marietta, Ga., is scheduled after the spring holidays.

Two members presented papers at the conference at Virginia Polytechnic Institute. Bill Knepsheild spoke on "Potential Applications of Plastics in the Aircraft Industry" and Fred P. Boesche on "Material Problems of Jet Engines."

University of Colorado

Jack W. Kenney, *Secretary*

Parents and friends of Jim Polosky, former Chairman of the IAS Student Branch at University of Colorado, attended the March 2 meeting for the presentation of a plaque and a photograph in his memory. Jim was killed last year while flying a Navy fighter. The name of the outstanding aeronautical engineer in each graduating class will be engraved on the plaque, which will be maintained by the IAS Branch.

Harvey C. Gerhard presided at the meeting. George Toumanoff, of Republic Aviation Corporation, spoke on the opportunities for new engineers in the aircraft industry. Mr. Toumanoff explained the development of a hypothetical airplane step by step, pointing out the various jobs to which new engineers were assigned at the Republic plant. He emphasized the need for experience and for the ability to write good and accurate English. He stressed the matter of composition to call attention to the troubles encountered in writing reports by engineers who have a poor knowledge of English.

Also present was Robert J. Naegele, of Lockheed Aircraft Corporation, who was interviewing senior engineering students for possible employment at the Missile Systems Division.

University of Illinois

James Baker, *Secretary*

The University of Illinois Student Branch held its third meeting of the semester on March 21 in the Electrical Engineering Building at Urbana.

Chairman Jim Kuczma called the meeting to order. As there was no new business to be brought before the group, the meeting was turned over to H. H. Hilton, Faculty Adviser.

Mr. Hilton introduced the guest speaker of the evening, Harry Tobey, Chief of Structures for the Piasecki Helicopter Corporation.

Mr. Tobey gave an introduction to the basic principles of helicopter operation. A color movie of the Piasecki YH-16 was shown. The film gave several sequences of early flight tests, as well as views of some of the interior and exterior details of this helicopter. The Piasecki YH-16 is the largest helicopter in existence today, and this was vividly illustrated by some shots of jeeps and armed troops moving out of the 'copter and down the large loading ramp at the rear of the fuselage.

Following the movie, several slides were shown. These slides showed in more detail the drive linkage for the tandem twin-engined helicopter, some details of the planetary gear system for the rotor, and the complex control system required.

Mr. Tobey mentioned that designing a helicopter was much like writing a quiz—they both looked all right until the flight testing or the grading started.

Following the talk there was a lively and interesting question-and-answer period. Some of the questions dealt with topics such as single-engine operation, basic stability, design load factors, and control problems.

University of Maryland

George Maggos
Secretary-Treasurer

The Maryland Student Branch held its monthly meeting in the Engineering Building on March 16, with 18 members present. The four members who had been sent by the Branch to Brooklyn Polytech reported on how the Northeastern Regional Student Branch Conference was conducted. Worth-while information was presented which, it was felt, would aid our Branch if we were host to a conference next spring.

Plans were made for the annual banquet and spring picnic. Arrangements were made for those who planned to go to Virginia Polytechnic Institute for the Southeastern Regional Conference for Student Branches on April 7-9. The meeting closed with a showing of films on the Martin PBM3 wing structural test, the Handley Page Crescent Wing, and North American's F-100A Super Sabre.

University of Michigan

Robert R. Jones, *Secretary*

The University of Michigan Student Branch held a short but important business meeting on March 29. Thirty members and the Faculty Adviser, Mr. Morrison, were present.

Four subjects were discussed—the Engineering Open House scheduled for April 23, the Regional Paper Contest to be held in Ann Arbor at the end of April, the American Rocket Society, and the Flying Club. Mr. Morrison spoke on the activities of the ARS and the interest they might hold for a college student. After a lengthy discussion of the possibility of buying a used light plane, it was decided that each member, during spring vacation, make a personal survey as to the actual cost of a used plane and report what he learned at the next meeting.

Roger J. Nyenhuis, *Secretary*

The March 8 meeting of the IAS Student Branch of the University of Michigan was called to order by Chairman Bob Lauer. The first order of business was the election of Bob Jones as Secretary for the coming year. The Chairman also urged members to attend the Slide Rule Ball, an annual social event sponsored by the Engineering Council.

Alfred Eggers of the NACA was the speaker of the evening. His talk dealt with the hypersonic wind tunnel at the Ames Aeronautical Laboratory. Hypersonic flows were defined as those having a Mach Number greater than 5.

The problems being studied in hypersonic flows were broken into three main categories. The first problem is to determine an efficient lifting surface with low drag, or rather, a shape with a high L/D ratio. The second problem is concerned with stable and controlled flight. Mr. Eggers pointed out that as the Mach Number increases, less and less air is affected by the passage of the airfoil, and consequently the problem of maintaining control by aerodynamic means arises. The third general problem being investigated is concerned with aerodynamic heating in a hypersonic flow and the associated thermal stresses.

Next, Mr. Eggers enumerated some of the wind-tunnel complications that arise in attempts to obtain hypersonic flows. The first complication he mentioned concerned the high pressure ratio required to obtain Mach Numbers above 5. A second difficulty is maintaining the Reynolds Number per foot. A final complication is the need for higher stagnation temperatures to prevent condensation in the tunnel test section and give more realistic test results.

Two methods for avoiding these difficulties, according to Mr. Eggers, are to use helium as the working fluid in the tunnel or to use the ballistic method. The ballistic method consists of firing a model upstream through the test section where pictures are taken and on through the wind-tunnel-nozzle throat, beyond which the model is arrested. An advantage of the ballistic method is that the wind tunnel is not required to provide an airflow faster than Mach 2.

Slides were shown to illustrate Mr. Eggers' talk. A motion picture showed a model made of Wood's metal being melted by aerodynamic heating.

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▶ The meeting of February 9 was called to order by Chairman Bill Sproull and the first business was to have the Institute picture taken for the *Michigan Ensian*. Approximately 55 members were present for the picture, and there were 72 present for the meeting. Eighteen new members were enrolled.

Our Faculty Adviser, Maurice Brull, explained the requirements for the St. Louis Student Paper Competition and also the benefits that could be obtained from writing such a paper. He strongly advised students who had the time to start work on a paper now so as to have sufficient time to think about the subject material.

Officers were elected for the coming year. They are Robert Lauer, Chairman; Donald N. Lascody, Vice-Chairman; and Frederick L. Stegenga, Treasurer.

Paul Titus, from the Columbus plant of North American Aviation, Inc., was the speaker this evening. Preceding his talk, Mr. Titus had a film of the North American F-100 shown. This film showed the F-100 in various attitudes of flight, including landing and take-off. After the film, Mr. Titus discussed some of the problems encountered while designing and testing the airplane. The meeting closed with the showing of a film entitled *The History of the Helicopter*.

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University of Pittsburgh

John M. Vasilauskas, *Secretary*

The IAS Student Branch took an active part in the celebration of Engineers' Week, March 14–18, at the University of Pittsburgh. This started with a "mixer dance" for engineers and nurses. The following day, the engineering students took part in a chapel service and a parade. At mid-week, each engineering department showed displays at an Open House. The aeronautical engineering students exhibited a small smoke tunnel, a small working model of a ram-jet, and models of a supersonic wind tunnel, subsonic wind tunnel, and water channel. The week closed with the Shamrock Ball at West View Danceland.

University of Tulsa

Lloyd T. Richardson
Secretary-Treasurer

A regular meeting of the University of Tulsa Student Branch was held on March 25. Chairman Don Boyd opened the meeting with a reminder that the Scholastic and Lecture Awards would have to be announced soon. Anyone wishing to compete for the Lecture Award was urged to prepare his paper as soon as possible.

It was announced that the opportunity had arisen to get a professional speaker for our next meeting. The speaker, A. H. Hasbrook, Director of Aviation Crash Injury Research, was scheduled to be in the state during April and agreed to give a talk at our meeting on April 15.

It was pointed out that this meeting should be heavily publicized in order to assure as large a turnout as possible. The decision was made to invite the engineers from Douglas Aircraft Company and American Airlines to attend.

A film entitled *Masters of Maintenance* was shown before the meeting closed. The film showed the countless continual checkovers given an air liner during its use. It described the procedures for keeping the planes in tip-top shape for maximum safety and optimum performance, including the regularly scheduled overhauls as well as the minor repairs of small troubles reported by crew members. The film was shown through the courtesy of American Airlines and was a description of the company's maintenance program on the DC-7.

▶ The University of Tulsa Student Branch sponsored a field trip through the Tulsa plant of Douglas Aircraft Company, Inc., on March 11. The tour was

conducted by Tod Miller, one of our members who is employed at Douglas in the Training Department. Mr. Miller conducted the group through the plant in the order of production steps and then through the Engineering Department.

Besides producing the Boeing B-47, the Douglas Company is in the primary stages of production on the Douglas B-66 bomber. Approximately half of the plant is used for the production of each airplane, although some smaller contracts for parts of other planes are also handled at the Tulsa Douglas plant.

In the Engineering Department we saw mainly the design groups. The tour had to be cut somewhat short because of the change of shifts at the plant. The ten who went on the trip generally agreed that it had been interesting and educational.

University of Washington

Bud D. Nelson
Secretary-Treasurer

At an evening meeting March 31, the University of Washington Student Branch had as its guest speaker Mr. Cathaway, Group Engineer, Stability and Control Section, Lockheed Aircraft Corporation.

Mr. Cathaway was introduced by Chairman Glenn W. Stinnet before his talk on "Design Problems for High Supersonic Fighters." He identified the problems confronting high supersonic fighters as:

(1) An engine must be built to power aircraft at M > 1. The afterburner engine has so far provided this answer.

(2) The drag due to wing thickness has required that thickness ratios of 3 per cent be employed, thus eliminating the storage capacity of the wing and presenting a structural problem.

(3) Drag of various plan forms has shown that straight wings have less drag when M > 1.5.

(4) The straight wing also has better performance at high altitudes.

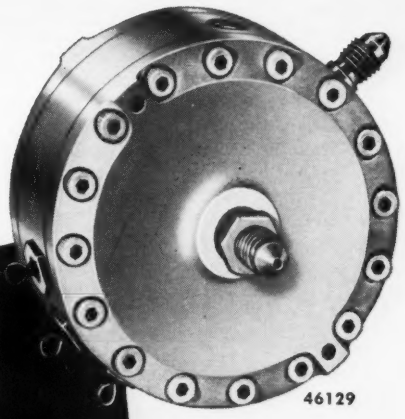
(5) Comparison of drag at M = 0.8 and M = 1.6 has shown a large increase in small-drag producers such as protuberances and fillets.

(6) High horizontal stabilizers and all-movable tails provide additional structural problems.

Mr. Cathaway presented two films, entitled *Lockheed Research on Wing Design* and *New Lockheed Prototypes*. The latter was highlighted by flight shots of the XFV-1, including the transition into vertical flight.

▸ An afternoon meeting was called on March 21. Twenty-five members met in Guggenheim Hall to hear a talk on "Flow Visualization" presented by Victor Stevens, Assistant Chief of the

transmission of pressure information



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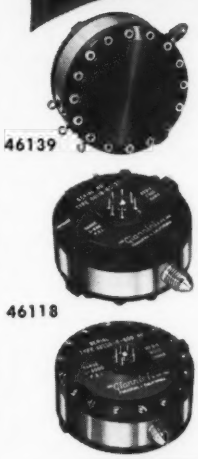

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High-Speed Research Division, Ames Aeronautical Laboratory, NACA.

Mr. Stevens said an effort for more complete understanding of actual flow around a body is the reason for various flow techniques. With the aid of slides and movies, he explained the methods used by the NACA—smoke flow, tuft grid, and water tank have been used for low-speed testing.

The water tank method was of interest to all present, as it represents a cheap means of flow visualization on student-designed models. The model is prepared by painting the wing trailing edge with silver powder. The model is then lowered slowly into water. The powder remains on the water surface to show vortex paths. Mr. Stevens gave special emphasis to flow visualization at high speeds and described the use of schlieren, shadowgraph, and vapor-screen methods.

As problems in design, Mr. Stevens pointed out some characteristics of high-speed aircraft which can be observed by schlieren photography, shadowgraph, and vapor screen. Long fuselages with high fineness ratio can produce mixed flow at the tail, he said. Low aspect ratio wings produce high vortices near the fuselage. Vortex motion, therefore, has become a strong influence in design. Mr. Stevens said that as airplane speeds increased, flow vizualization had proved useful as a guide for new theory.

University of Wichita

J. F. Cox, *Secretary*

The Student Branch of the University of Wichita held its third meeting of the semester on March 21 in the Engineering Library, with 27 present. Mr. Marshall, of North American Aviation, Inc. (Columbus Division), spoke on a number of engineering problems, including rudder shake caused by shock waves being out of frequency, wing drop, etching of wings, and low-speed fences. Following his talk, he showed a film on the North American FJ-4 Fury. Plans were made for reviewing students' papers to be entered in the Third Annual Student Competition sponsored by the Texas Section of the IAS.

▶ Thirty-seven persons, including a number of guests and faculty members, attended the March 1 meeting to hear Mr. Heppe, of Lockheed Aircraft Corporation, speak on problems encountered in the design of high-speed aircraft. Mr. Heppe opened his talk with a few general comments on the Lockheed F-104. Next came a comparison of present and future fighter planes. He said two of the most important recent design improvements were the development of thin wings and of larger fuselages as compared to wings. He compared drag, performance, and the influence of various design features at subsonic and supersonic speeds.

A film was presented showing first flight pictures of the Lockheed C-130A Hercules and various shots of the P2V-7 Neptune, WV-2 Constellation, T2V-1 Navy jet trainer, and the XFV-1 VTO fighter. Another film was shown covering aeroelastic problems.

▶ Fifty members attended the February 24 meeting to hear James Reagan speak on the development of missiles and on problems that may be encountered in future development. Mr. Reagan discussed missile structure, propulsion systems, and guidance systems. He covered Germany's development of missiles during World War II and the development of various types in the United States.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Beerer, Joseph G., B.S.M.E. (Aero.), Dir., Aerophysics Dept., North American Aviation, Inc. (Downey).

Dunn, Leigh, B.S.Ae.E., Chief Engr., Test Subdiv., Marquardt Aircraft Co.

Jewett, R. H., B.S., Chief Engr., Pilotless Aircraft Div., Boeing Airplane Co. (Seattle).

Loftin, Laurence K., Jr., B. of M.E., Sect. Head, General Aerodynamics Sect., Full-Scale Research Div., Langley Aero. Lab., NACA.

Posner, David L., B.M.E., Power Plant Staff Specialist, Lockheed Aircraft Corp. (Marietta).

Szukiewicz, R., Ing. Dipl., Asst. Chief Aerodynamicist, Airspeed Div., The de Havilland Aircraft Co., Ltd. (England).

Transferred to Associate Fellow Grade

Duppstadt, J. Robert, B.S. in M.E., Experimental Proj. Engr., Bell Aircraft Corp.

Hinz, Earl Robert, M.S., Research Group Engr.—Head, Stability & Control Group, Ryan Aeronautical Co.

Hong, James, B.S. in Ae.E., Div. Engr.—Aerodynamics, Lockheed Aircraft Corp. (Burbank).

Josephs, Lyman C., III, B.S., Chief Proj. Engr., Chance Vought Aircraft, Inc.

Elected to MEMBER Grade

Beals, Vaughn L., Jr., M.S., Aero. Engr., Dynamics Group, North American Aviation, Inc. (Columbus).

Carpenter, Randall H., B.A., Mgr., Air Transport Div., Flight Safety Foundation.

Clark, J. J., A.B., Admiral, USN (Ret.), V-P—Administrative, Radio Receptor Co., Inc.

Collier, Irwin L., B.S. in M.E., Test Proj. Control Engr., Allison Div., General Motors Corp.

Corning, Gerald, M.E. in Ae.E., Assoc. Prof.—Aero. Engrg., Univ. of Maryland.

Dill, Robert P., B.S.M.E., Engrg. Designer, Aerophysics Development Corp.

Evans, William L., M.S.E.E., Sr. Aerophysics Engr., Automatic Controls Group, Convair, Fort Worth, A Division of General Dynamics Corp.

Forlifer, William R., B.S. in M.E., Staff Specialist—Dynamics, Van Zelm Associates, Inc.

Gahn, Edwin H., B.S.E.E., Sr. Proj. Engr., The Greenleaf Manufacturing Co.

Gurney, Marshall B., B.S., Dir., Aero. Div., General Bronze Corp.

Haller, George E., B.S.E., Supvr.—Contract Administration, Aircraft Accessory Turbine Dept., General Electric Co. (West Lynn.)

Heller, J. A., B.S., Engrg. Specialist, Thermodynamics & Propulsion Sect., Goodyear Aircraft Corp.

Helms, Harold E., M.S.M.E., Sr. Project Engr., Stress Analysis Group, Allison Div., General Motors Corp.

Houghton, Argyle W., B.S., Proj. Engr., Aeronca Manufacturing Corp.

Ibanez, Henry, Sales Engr., Kenyon Instrument Co., Inc.

Jackson, Harry B., B.S.M.E., Unit Supvr., Combustion & Augmentation Mechanical Design Unit, Devel. Engine Sect., General Electric Co. (Evendale).

Jacobson, Morton, B.S.M.E., Sr. Project Engr., Allison Div., General Motors Corp.

Katz, Ellis, B.S., Head, Dynamics Analysis Sect., Guided Missiles Div., Fairchild Engine & Airplane Corp.

Keller, William J., Layout & Design Work, Allison Div., General Motors Corp.

Little, Robert C., B.S.M.E., Chief Test Pilot, McDonnell Aircraft Corp.

Maedel, Paul H., Jr., M.S.M.E., Supervising Engr., AGT Experimental Devel. Lab., Westinghouse Electric Corp.

Murasaki, Toshimitsu, Instructor, Research Assoc., Institute of Science & Technology, Tokyo University.

Murphy, Charles H., Jr., M.S. in Engrg.—Aeronautics, Deputy Chief, Free Flight Aerodynamics Branch, Ballistic Research Laboratories.

Neumann, Gerhard, Mgr., Devel. Engine Sect., AGT Div., General Electric Co. (Evendale).

Olson, Bruce D., Proj. Engr.—Struct., American Airlines, Inc. (Tulsa).

Peller, William N., B.S.M.E., Design Engr., McDonnell Aircraft Corp.

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Pride, Richard A., B.S. in C.E., Aero. Research Scientist—Structures, Langley Aero. Lab., NACA.

Reddy, Joseph L., B.M.E., Technical Engr., General Electric Co. (Evendale).

Rees, Pembroke G., B.S., Loads Engr., McDonnell Aircraft Corp.

Robinson, George H., Jr., B.S., Stress Engr., Aircraft Div., Zenith Plastics Co.

Sando, Robert M., B.S. in Ae.E., Sr. Engr., Devel. Engrg. Staff, Air Arm Div., Westinghouse Electric Corp. (Baltimore).

Sawyer, John M., B.S. in Ae.E., Design Engr. "A," Lead Designer, Wind Group, Temco Aircraft Corp.

Schwartz, James E., B.S., Mgr.—Aviation Sales General Electric Co. (Wash., D. C.).

Shereika, Edmund A., Sr. Designer, Walter Kidde & Co.

Taylor, H. W., B.Sc., Requisition Systems Engr., Flight Control Systems, A. & O.S. Div., General Electric Co. (Schenectady).

Veneklasen, Paul S., M.S., Owner-Dir., Western Electro-Acoustic Laboratory.

Webster, Robert A., B.S. Aero., Aerodynamics Engr., Ryan Aeronautical Co.

Weikel, Raymond C., A.M. in Math., Assoc. Prof.—Aero. Engrg., Univ. of Washington; Struct. Engr., Boeing Airplane Co. (Seattle).

Wetmore, William H., M.S.M.E., Supvr.—Advanced Analysis, Jet Engine Dept., General Electric Co. (Evendale).

Williams, Robert M., M.S.Ae.E., Head, Dynamics Sect., Struct. Test Group, Lockheed Aircraft Corp. (Marietta).

Williams, William G., B.S.Ae.E., Technical Engr.-Engine Installation Specialist, Product Planning Sect., AGT Div., General Electric Co. (Cincinnati).

Transferred to MEMBER Grade

Arthur, Paul D., Ph.D., in Aeronautics, Systems Analyst, Guided Missile Research Div., Member of Technical Staff, Ramo-Woolridge Corp.

Celniker, Leo, M.S., Aerodynamics Engr., Lockheed Aircraft Co. (Los Angeles).

Christiansen, George A., Member, Air Frame Struct. Group—Stress Analysis, Bell Helicopter Div., Bell Aircraft Corp.

Donovan, Charles G., Sr. Design Engr.—Preliminary Design, Convair, Fort Worth, A Division of General Dynamics Corp.

Doty, R. J., Jr., M.S. in Ae.E., Design Specialist "B," Boeing Airplane Co. (Wichita).

Fiore, Anthony W., M.S., Sr. Aerodynamics Research Scientist, Fluid Dynamic Branch, Aero. Research Lab., WADC, Wright-Patterson AFB.

Gomez, Guillermo Gonzalez, B. of Engrg., Aero. Engr., Engrg. Office, San Carlos Univ. (Guatemala).

Hoffman, Willard A., A.A., Sr. Engr., Flight Test, North American Aviation, Inc. (Columbus).

Lemm, Rollin G., M.S., Research Asst., Willow Run Labs., Univ. of Michigan.

McComb, Harvey G., Jr., M.S. in Ae.E., Aero. Research Scientist, Langley Aero. Lab., NACA.

Patton, Robert J., M.S. in Ae.E., Sr. Aerodynamics Group Engr., Convair, Fort Worth, A Division of General Dynamics Corp.

Ricles, Robert E., B. of Ae.E., Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Roe, Marshall H., M.S. in M.E. (Aero.), Sr. Engr.—Aerodynamics, North American Aviation, Inc. (Los Angeles).

Sisto, Fernando, Jr., Sc.D., Project Engr.—Supervision of Design Unit, Research Div., Wright Aero. Div., Curtiss-Wright Corp.

Smith, William E., M. of Ae.E., Asst. Research Aerodynamicist, Aerodynamic Research Dept., Cornell Aeronautical Laboratory, Inc.

Tate, Roger E., B.S., Wind Tunnel Test Engr. "A," Convair, Daingerfield, A Division of General Dynamics Corp.

Weiner, Frederick R., M.S., Design Engr.—Research & Devel., North American Aviation, Inc. (Los Angeles).

Elected to Associate Member Grade

Conklin, Roland H., B.S., Operations Research Cost Analyst, Lockheed Aircraft Corp. (Burbank).

Grant, Walter, Executive Asst., Rheem Manufacturing Co.

Henderson, C. R., Experimental Assembly Control Engr., Allison Div., General Motors Corp.

Imrie, Walter C., M.A. in Economics (Air Transport), Staff Specialist—Air Transportation, Operations Research Div., Lockheed Aircraft Corp. (Marietta).

Pearman, Horace C., Asst. to B-52 Proj. Test Engr., Boeing Airplane Co. (Seattle).

Tower, Merrill F., B.S., Coordinator-Aviation Education & Aeronautics Instructor, Board of Education, Los Angeles City High School.

Transferred to Associate Member Grade

Stickel, Edward L., Book Engr., Boeing Airplane Co. (Seattle).

Elected to Technical Member Grade

Ashford, Charles T., III, B.S. in M.E., Aerodynamics Engr., Convair, Fort Worth, A Division of General Dynamics Corp.

Broecker, Harold W., B.S.A.E., Jr. Engr.—Research & Devel., Cook Research Labs. Division, Cook Electric Co.

Donohoe, John C., A.B., Assoc. Engr., The Glenn L. Martin Co.

Forsyth, Robert W., Computer, Aerodynamics Div., Lockheed Aircraft Corp. (Burbank).

Friedlund, Donald R., B.S.A.E., Jr. Engr.—Research & Devel., Cook Research Labs. Division, Cook Electric Co.

Gomez, Edvardo W., B.S., Struct. Engr., Convair, Fort Worth, A Division of General Dynamics Corp.

Greismer, William C., Engrg. Draftsman, North American Aviation, Inc. (Columbus).

Harty, Richard B., M.S. in Ae.E., Aero. Engr., Aerodynamics Sect., Marquardt Aircraft Co.

Loheed, H. B., B.S.E.E., Lt., USN; Navigator Instructor, NROTC Unit, Illinois Institute of Technology.

Riddhagni, B., M.Sc., 1st Lt., Engrg. Officer, Royal Thai Air Force (Bangkok).

Romig, Mary F., B.A. (Math.), Jr. Engr., Convair, San Diego, A Division of General Dynamics Corp.

Titus, Richard R., B.S., Engr.—Aerodynamics, North American Aviation, Inc. (Los Angeles).

Wykes, Robert C., B.S.M.E., Engr.—Aerodynamics, North American Aviation, Inc. (Columbus).

Transferred to Technical Member Grade

Ahls, William L., B.S., 2nd Lt., USAF; Observer & Aircraft Maintenance Officer, Ellington AFB.

Ashraf, M. Akbar, B.Sc. In Aeronautics, Air Condition Engr., Ted Spangenberg Co.

Baldwin, L. C., A.E., Lt. & Naval Aviator, USN.

Beers, Harold S., Jr., B.S.A.E., Ens. & Student Naval Aviator, USN.

Bruns, John H., B.S., Engr., Cessna Aircraft Co.

Carl, John G., M.S.E., Lt. & Power Plant Officer, USN.

Carr, William E., B.S.A.E., Assoc. Engr., Missiles Aerodynamics Sect., Douglas Aircraft Co., Inc. (Santa Monica).

Clark, Frank L., B.Ae.E., Aero. Research Intern, NACA, Langley AFB.

Clark, Harold L., B.S.A.E., Lt. & Asst. Engrg. Officer, USAF.

Crotty, Patrick B., B.S. in Ae.E., Aerodynamicist, McDonnell Aircraft Corp.

Davis, Walter B., Jr. Engr., Ryan Aeronautical Co.

Dawson, Paul L., M.E., Staff Engr., Solar Aircraft Co.

Doty, D. L., B.S., Jr. Aerodynamics Engr., North American Aviation, Inc. (Columbus).

Entz, Roger D., B.S. in Ae.E., Jr. Engr., Armament Group, Douglas Aircraft Co., Inc. (El Segundo).

Ferns, Leo C., Jr., Struct. Mechanic, Lockheed Aircraft Service, Inc.

Fisher, William Lee, B.S., 2nd Lt. & Flight Trainee, USAF.

Fleming, Joseph, A.S.E., Engr.—Rocket Engine Design, North American Aviation, Inc. (Los Angeles).

Frankel, Alvin L., M.S., Mechanical Engr., Hughes Aircraft Co.

Frankel, M. A., M.S. Engrg., Aerodynamicist "A," Northrop Aircraft Co.

Giannetto, Charles, Design Engr., Engineering & Research, A Division of A.C.F. Industries, Inc.

Gibson, James D., Jr., Designer, Goodyear Aircraft Corp.

Grifall, William J., B.S., Jr. Engr.—Aerodynamicist, North American Aviation, Inc. (Downey).

Harmon, Robert E., B.S., Technical Rep., Allison Div., General Motors Corp.

Hearn, H. D., B.S., Flight Test Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

Hoffman, Myron A., M.S., Instructor, Massachusetts Institute of Technology.

Hollub, Raymond M., Assoc. Aircraft Engr., Lockheed Aircraft Corp. (Marietta).

Jawor, Cheslav F., B.S.A.E., Jr. Engr., Douglas Aircraft Co., Inc. (Long Beach).

Johnston, Greg R., B.S. Air Trans., Naval Aviation Cadet, USN (Wash., D.C.).

Kearney, Stuart D., M.S. (Management Engrg.), Lt., USN.

Kolozsi, John J., B. of Ae.E., Lt. USAF; Engr., Industrial Engrg. Div., Deputy Chief Manufacture & Repair Branch, Hill AFB.

Kramer, Herbert, B.A., Administrator's Helper, 2029th AACS Squadron, Ellsworth AFB.

Land, Almos E., 2nd Lt., USAF.

Lazurenko, L. B., B.S., Graduate Student, Wayne Univ.

Lundby, Edward, Jr. Engr., Convair, San Diego, A Division of General Dynamics Corp.

Madayag, Angel F., M.S. in Ae.E., Stress & Vibration Engr., AiResearch Manufacturing Co.

Marroni, Michael A., Jr., B.S. in Ae.E., Stress Analyst, Douglas Aircraft Co., Inc. (Long Beach).

Marshall, Wayne T., B.M.E., Cpl., U.S. Army; Proj. Engr., Transportation & Devel. Command, Fort Eustis.

Mattson, Kenneth B., M.S. in Ae.E., Lt. USN; Fighter Squadron 192.

Milestone, Marshall L., B.S. in Ae.E., Jr. Engr., Convair, Pomona, A Division of General Dynamics Corp.

Miller, Gerald N., Assoc. Engr., The Glenn L. Martin Co.

Musialowski, Norman T., B.S.E., Aero. Research Scientist, NACA (Edwards).

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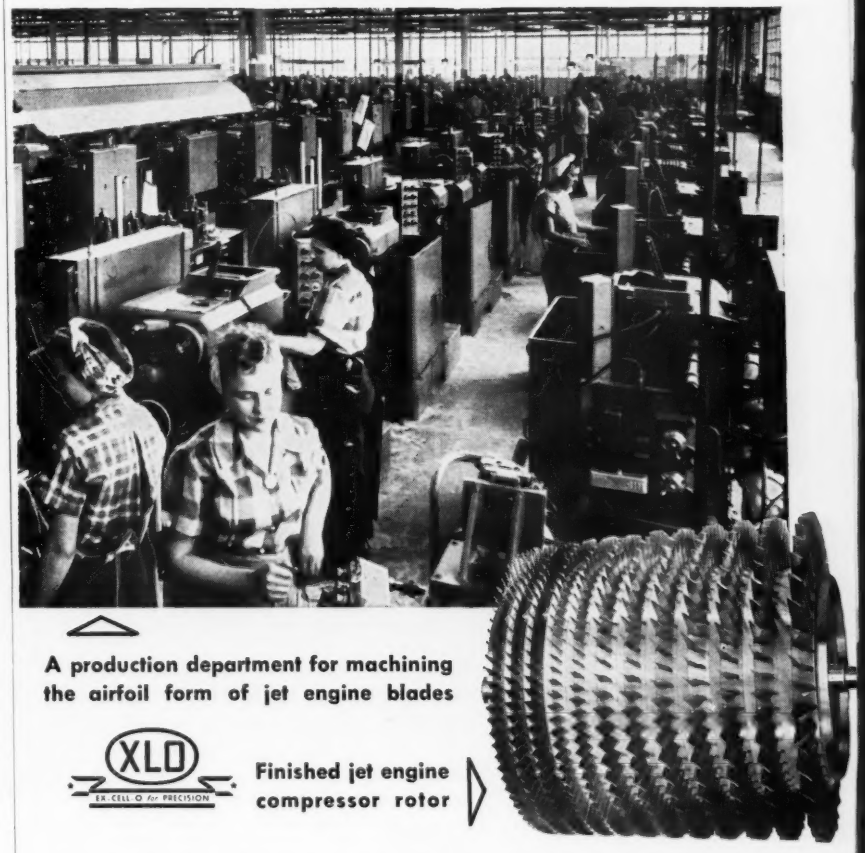

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I. PERIODICALS AND REPORTS

Aerodynamics 124
Boundary Layer & Thermoaerodynamics 124
Fluid Mechanics & Aerodynamic Theory 124
Internal Flow 124
Performance 127
Stability & Control 127
Wings & Airfoils 127
Aeroelasticity 127
Aeronautics, General 130
Air Transportation 130
Airplane Design 130
Control Systems 130
Development Testing 130
Landing Gear 130
Wing Group 130
Airports 130
Helicopter Stations 130
Traffic Control 130
Computers 131
Education & Training 134
Electronics 134
Amplifiers 134
Antennas 134
Communications 134
Construction Techniques 134
Electronic Tubes 134
Magnetic Devices 134
Measurements & Testing 134
Navigation Aids 134
Networks 134
Noise & Interference 134
Oscillators & Signal Generators 136
Radar 136
Semiconductors 136
Transmission Lines 138
Wave Propagation 138
Equipment
Electric 138
Hydraulic & Pneumatic 138
Flight Operating Problems
Weather & Climate 138
Flight Testing 138
Fuels & Lubricants 138
Gliders 138
Ice Formation & Prevention 138
Instruments
Automatic Control 138
Flow Measuring Devices 138
Recording Equipment 138
Stress & Strain Measuring Devices 140
Temperature Measuring Devices 140
Machine Elements
Bearings 140
Friction 142
Gears & Cams 142
Mechanisms & Linkages 142
Rotating Discs & Shafts 142
Springs 142
Materials 142
Corrosion & Protective Coatings 142
Metals & Alloys 142
Metals & Alloys, Nonferrous 142
Nonmetallic Materials 142
Sandwich Materials 142
Testing 142
Mathematics 142
Mechanics 144
Meteorology 144
Military Aviation & Armament 148
Missiles 148
Navigation 148
Noise Reduction 148
Photography 148
Power Plants 148
Jet & Turbine 148
Rocket 148
Production 148
Metalworking 148
Production Engineering 150
Tooling 150
Welding 150
Propellers 150
Reference Works 150
Rotating Wing Aircraft 150
Safety 150
Space Travel 151
Structures 151
Beams & Columns 151
Connections 152
Cylinders & Shells 152
Plates 152
Testing 152
Thermodynamics 152
Combustion 153
Heat Transfer 153
Wind Tunnels & Research Facilities 153

II. BOOKS REVIEWED IN THIS ISSUE

Mécanique Vibratoire. Robert Mazet **155**

Reviewed by R. H. Scanlan, Institut Blaise Pascal

Book Notes **156**

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Aerodynamics

Some Aerodynamical Aspects of High Speed Flight (Mainly Thrust and Drag). W. T. Truscott. *J. SLAE*, Mar., 1955, pp. 3–10. Includes analyses of propeller, turbojet, ram-jet, and nuclear propulsion, propulsive-lift elements, high-speed planforms, and choice of configurations.

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The Application of Finite Difference Methods to Boundary-Layer Type Flows. W. T. Rouleau and J. F. Osterle. *J. Aero. Sci.*, Apr., 1955, pp. 249–254. 13 refs. Development of the stepwise and implicit procedural representations of the Prandtl and continuity equations extending the Friedrich and Forstall method for axially symmetrical flow and with similar stability criteria, to derive solutions of the problems of the boundary layer over a flat plate with an arbitrary distribution of suction and the slot-jet issuing adjacent to a plate into a moving stream.

Boundary Layer Control. I—Boundary Layer and Circulation Control through Blowing and Sucking. II—Laminarisation through Boundary Layer Control. G. V. Lachmann. *J. RAeS*, Mar., 1955, pp. 163–194; Discussion, pp. 194–197; Author's reply, 197, 198. 57 refs.

Some Experiments in the Application of Boundary Layer Control. Joseph Flatt. *SAE Golden Anniv. Aero. Meeting, New York, Apr. 18–21, 1955, Preprint 513.* 10 pp.

The Compressible Laminar Boundary Layer with Fluid Injection. George M. Low. *U.S., NACA TN 3404*, Mar., 1955. 29 pp. 12 refs. Study of the method of transpiration cooling, taking into account the effect of several flow parameters on coolant-flow rates.

The Compressible Laminar Boundary Layer with Heat Transfer and Arbitrary Pressure Gradient. Clarence B. Cohen and Eli Reshotko. *U.S., NACA TN 3326*, Apr., 1955. 43 pp. 29 refs.

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Incompressible Non-Meridional Boundary Layer Flow on Bodies of Revolution. Artur Mager. *U.S., NAVORD Rep. 3366*, Sept. 13, 1954. 56 pp. 18 refs. Development of a theoretical method applicable to laminar and turbulent boundary-layer computations over slightly yawed bodies with or without the conditions of rotation about some axis in space.

Laminar Boundary Layer Behind Shock Advancing into Stationary Fluid. Harold Mirels. *U.S., NACA TN 3401*, Mar., 1955. 25 pp.

Investigation of the Turbulent Boundary Layer on a Yawed Flat Plate. Appendix A—Effect of Flow Divergence on Measured Boundary-Layer Growth. Appendix B—The Effect of Yaw and Roughness on Virtual Origin and Transition of an Artificially Thickened Boundary Layer; Effect of Yaw on Virtual Origin of Artificially Thickened Boundary Layer. Harry Ashkenas and Frederick R. Riddell. *U.S., NACA TN 3383*, Apr., 1955. 57 pp.

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Flow of Fluids. Murray Weintraub. *Ind. & Eng. Chem.*, Part II, Mar., 1955, pp. 558–565. 159 refs. Review of the literature on single-phase and multi-phase flows, flows through porous media, and mechanical design aspects.

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The Generalized Shock-Expansion Method and Its Application to Bodies Traveling at High Supersonic Air Speeds. A. J. Eggers, Jr., Raymond C. Savin, and Clarence A. Syvertson. *J. Aero. Sci.*, Apr., 1955, pp. 231–238, 248. 17 refs. Study of the shock-expansion method generalized to predict the whole two- and three-dimensional hypersonic flow field, including shock wave curvatures and resulting vorticity under certain conditions; comparison of theoretical predictions with experimental results for the surface pressures and bow shock waves of ogives at 2.7–6.3 Mach Numbers and angles of attack up to 15 degrees; extension of the two-dimensionality concept of inviscid three-dimensional hypersonic flows to steady boundary-layer flows.

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An Exact Solution of the Spherical Blast Wave Problem. J. Lockwood Taylor. *Philos. Mag. (7th Ser.)*, Mar., 1955, pp. 317–320.

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Analysis of Errors Introduced by Several Methods of Weighing Nonuniform Duct Flows. DeMarquis D. Wyatt. *U.S., NACA TN 3400*, Mar., 1955. 40 pp.

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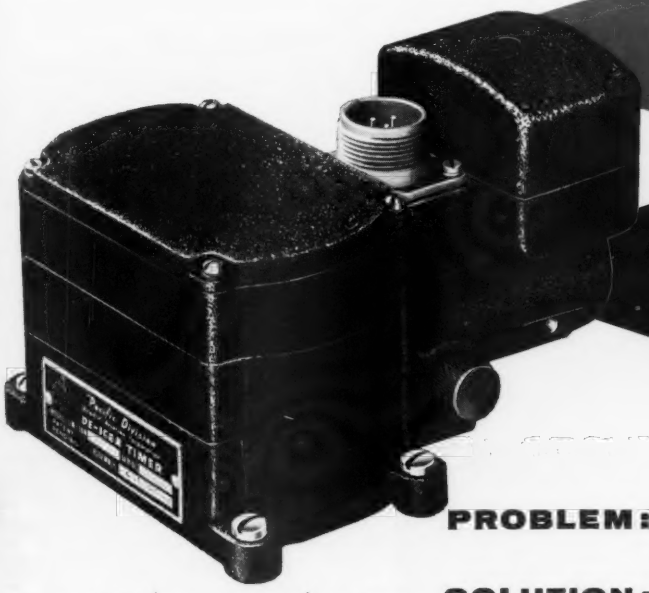

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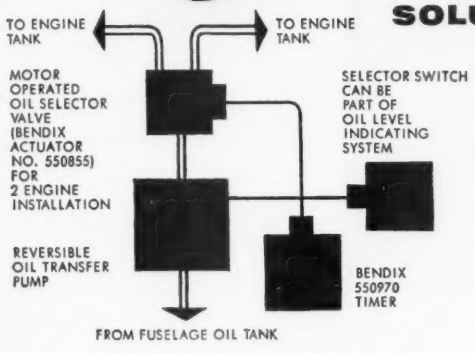
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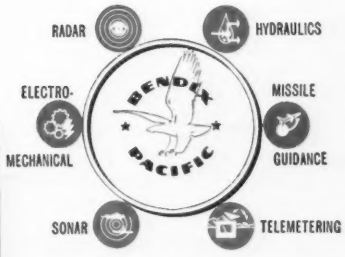

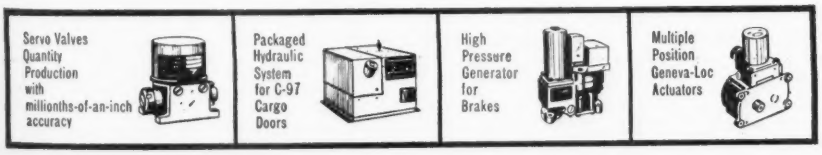
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Experimental and Theoretical Study of Transverse Vibration of a Tube Containing Flowing Fluid. R. H. Long, Jr. *J. App. Mech.*, Mar., 1955, pp. 65–68.

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A Rapid Approximate Method for the Design of Hub Shroud Profiles of Centrifugal Impellers of Given Blade Shape. Kenneth J. Smith and Joseph T. Hamrick. *U.S., NACA TN 3399*, Mar., 1955. 26 pp.

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Static Stability of Fuselages Having a Relatively Flat Cross Section. William R. Bates. *U.S., NACA TN 3429*, Mar., 1955. 29 pp.

Theoretical Calculations of the Pressures, Forces, and Moments Due to Various Lateral Motions Acting on Thin Isolated Vertical Tails with Supersonic Leading and Trailing Edges. Kenneth Margolis. *U.S., NACA TN 3373*, Mar., 1955. 43 pp. 18 refs.

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Aerodynamics of a Rectangular Plate with Vortex Separation in Supersonic Flow. H. K. Cheng. *J. Aero. Sci.*, Apr., 1955, pp. 217–226. 33 refs. Theoretical solution for the flow field in the tip region using a simplified mathematical model for approximating the phenomenon of vortex separation from the side-edge, with the results given in terms of the strength or the circulation of the free vortex system, the equation of the vortex core in space, and the nonlinear lift as well as its center of pressure.

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The Power-Lift Principle for Low Speed Flight. William E. Hunt. *Aeronautics*, Mar., 1955, pp. 26–29.

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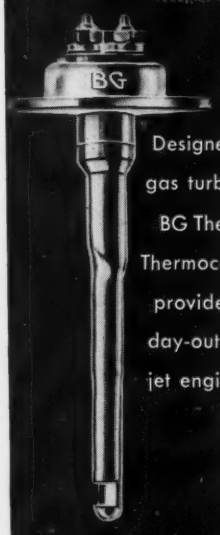

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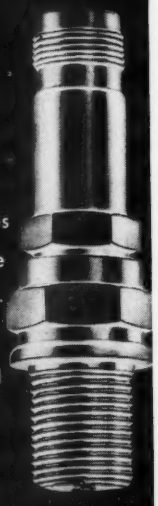

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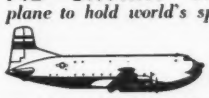

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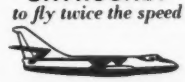

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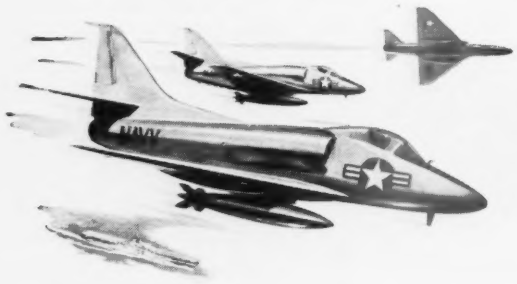

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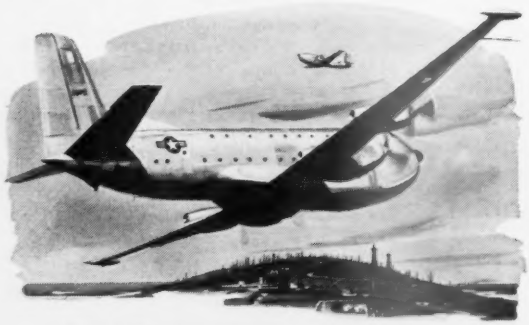

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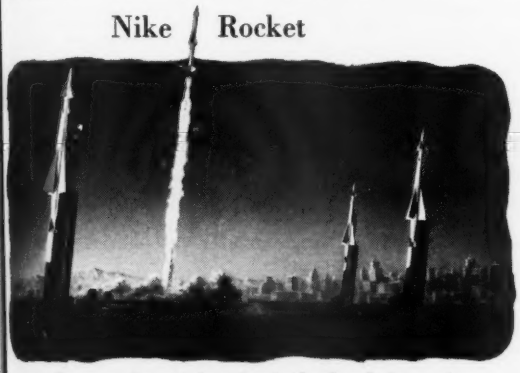

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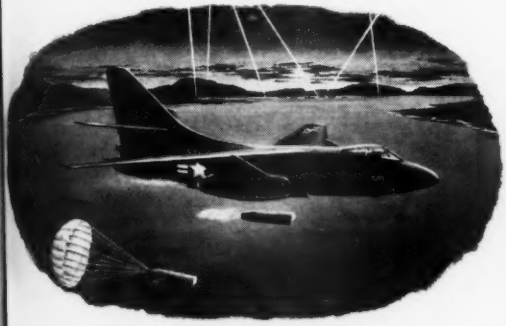

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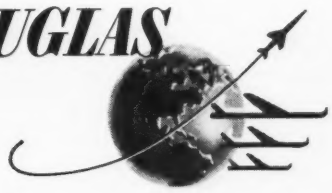

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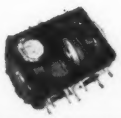
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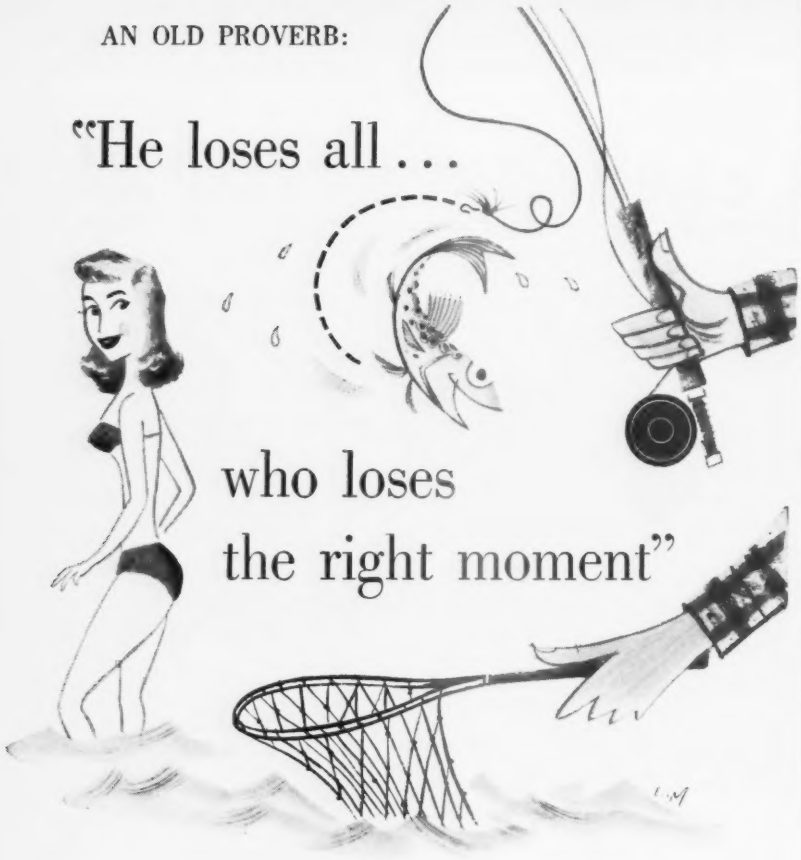

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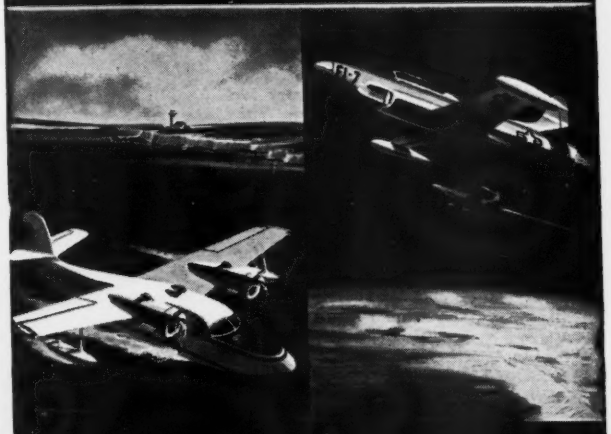

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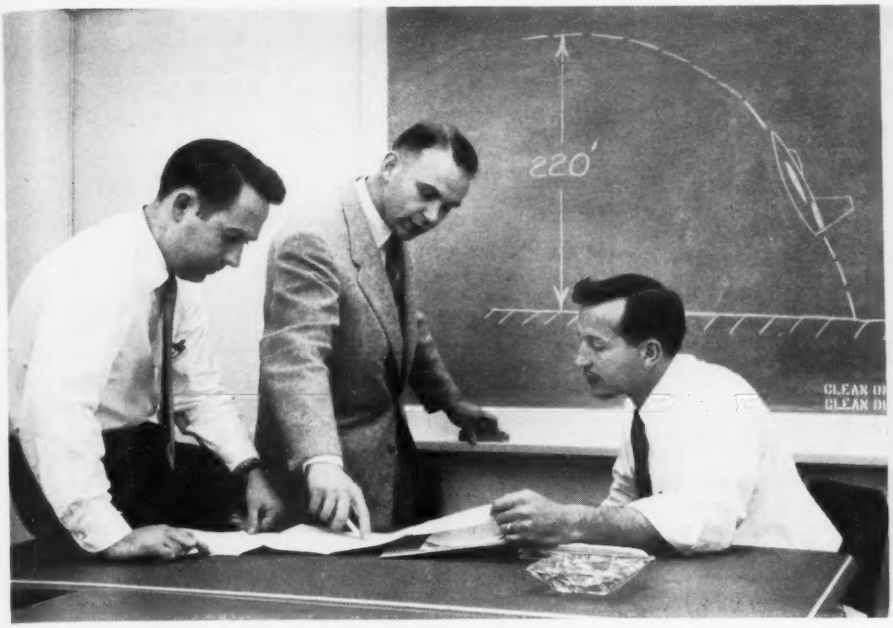

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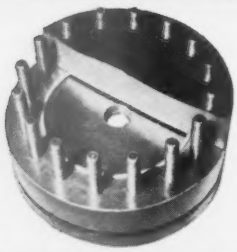

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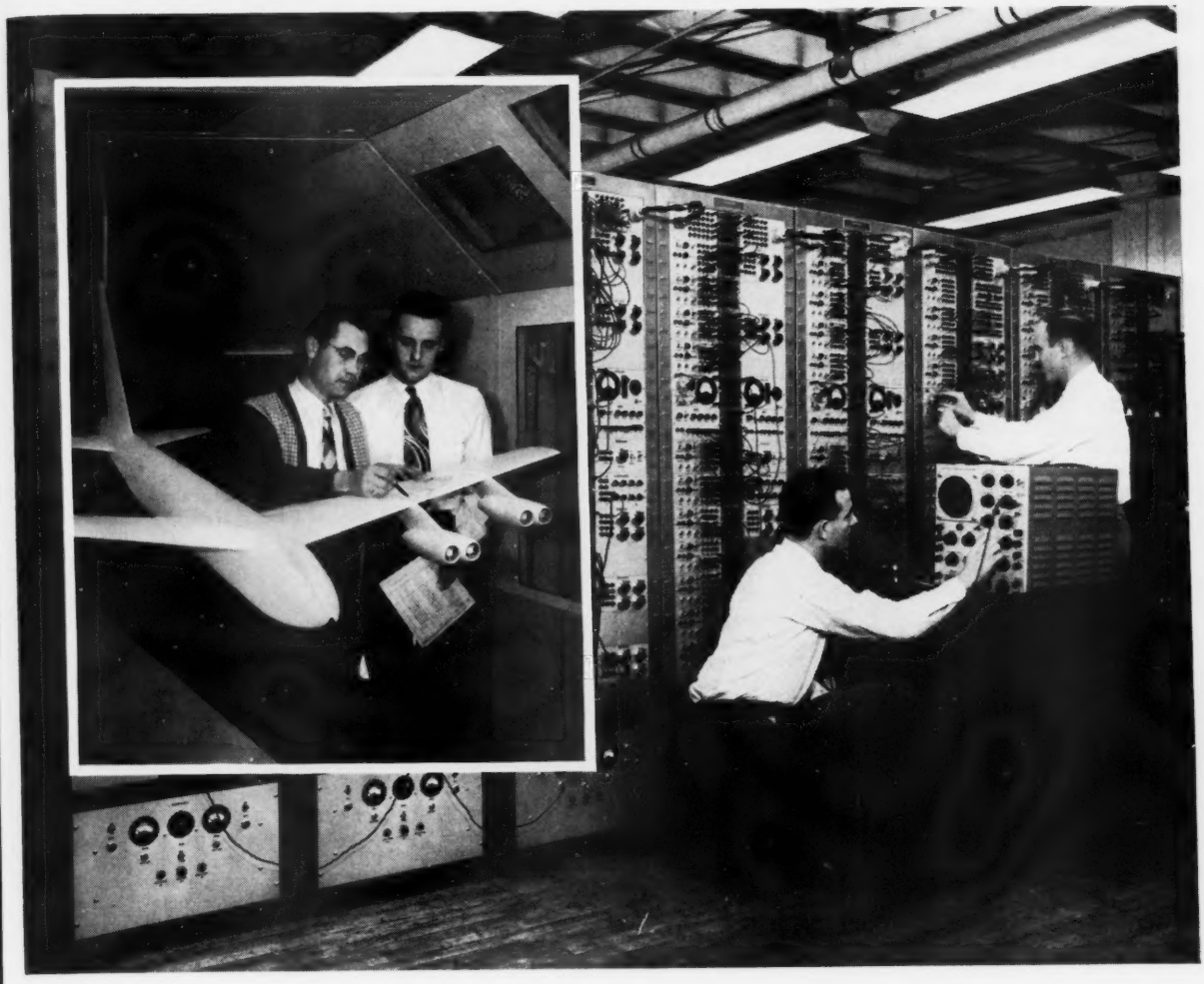

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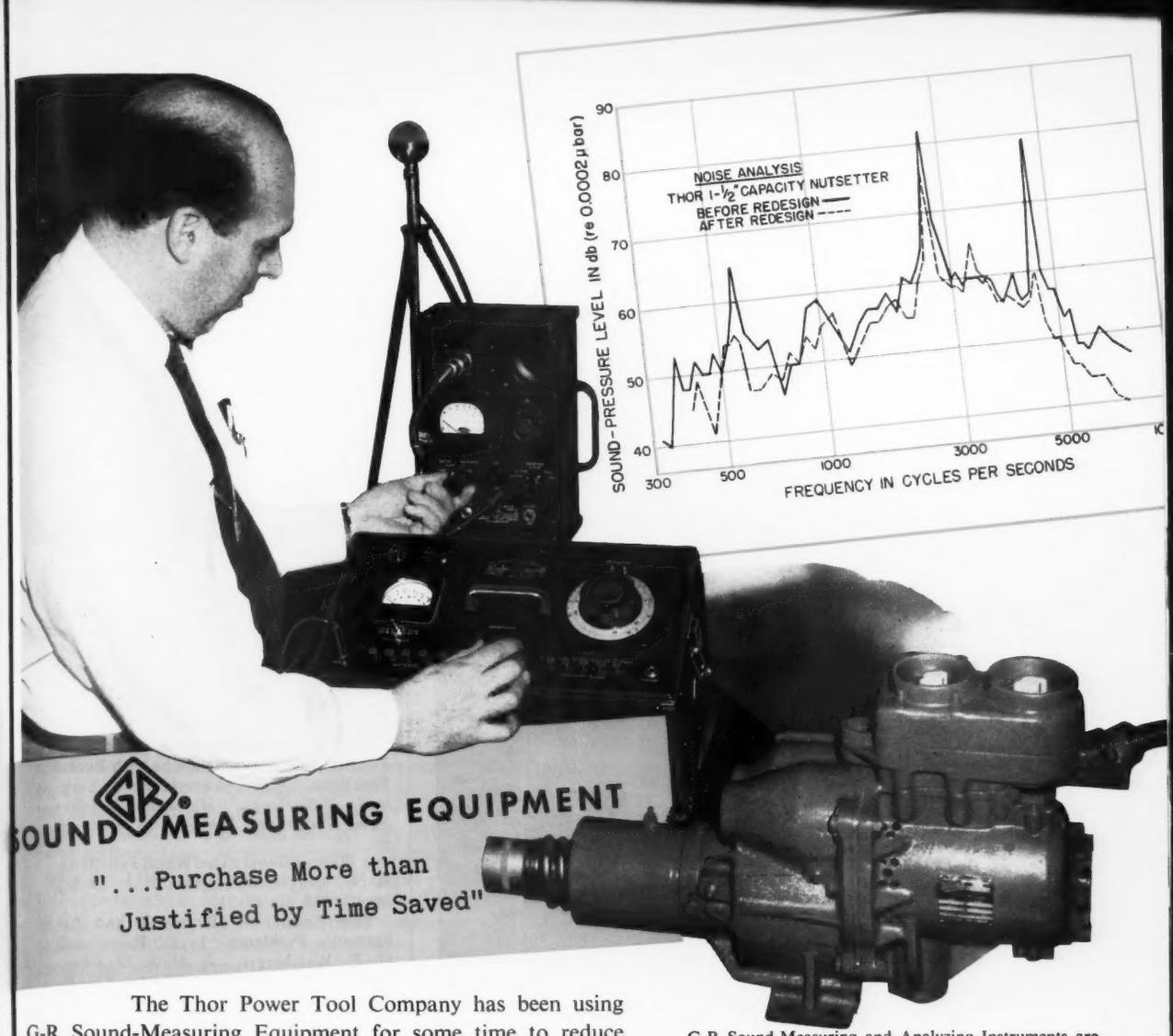

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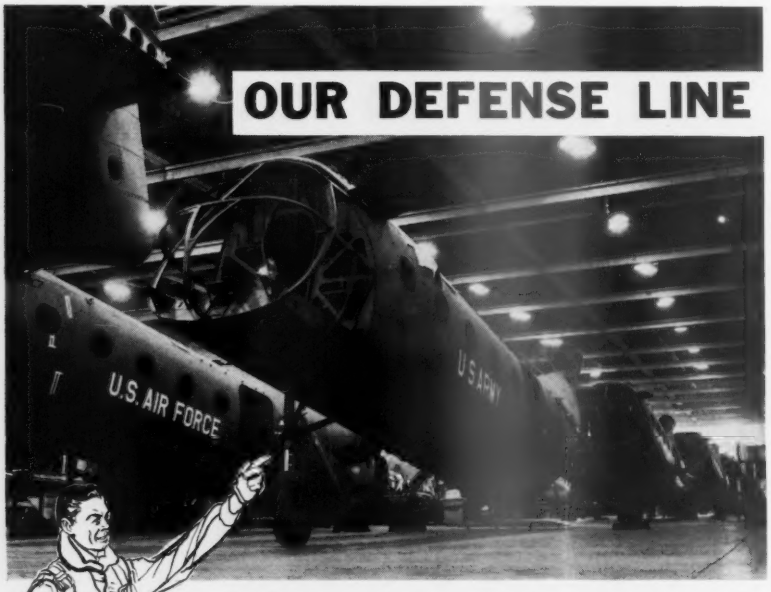

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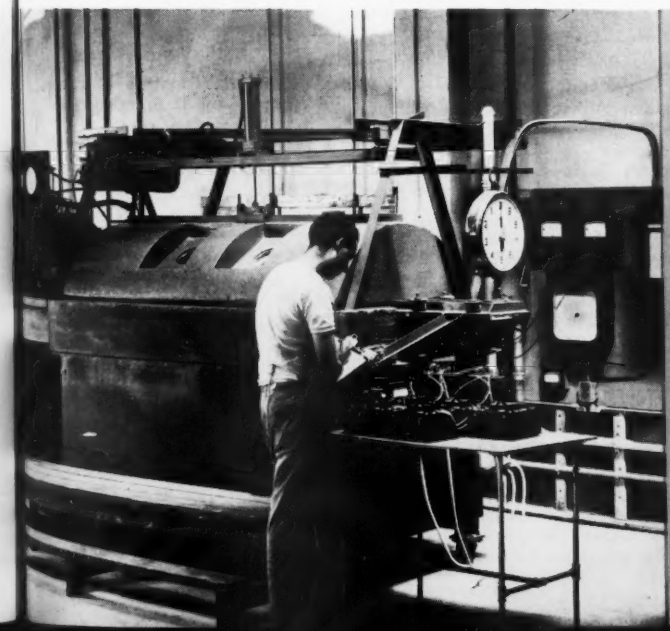

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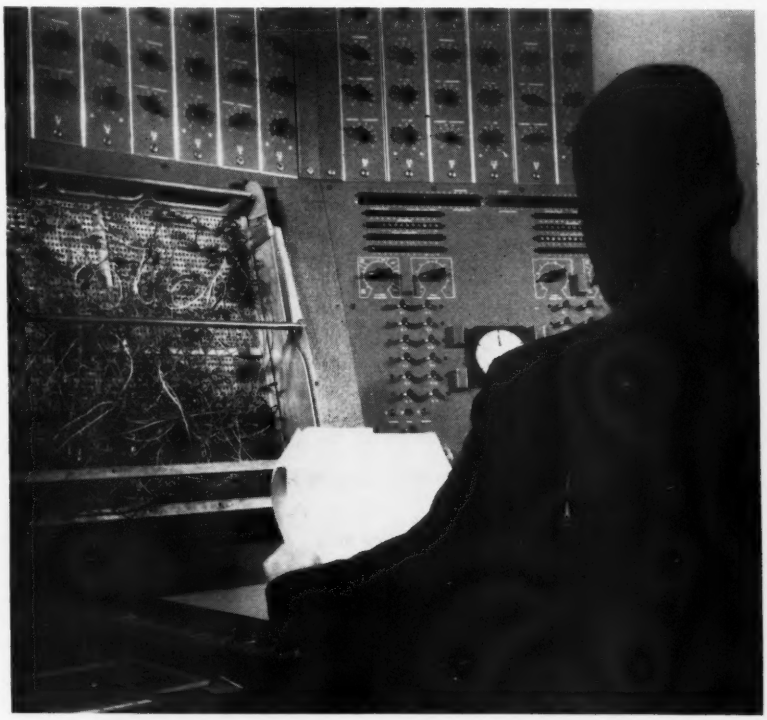

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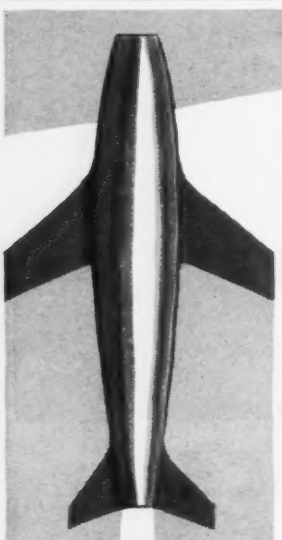

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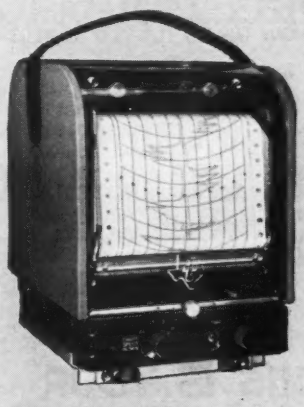

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Aeronautical Reviews — BOOKS

Mécanique Vibratoire

By Robert Mazet. Paris, Librairie Polytechnique Ch. Béranger, 1955. 280 pp., figs. $15.

This book represents the course in vibration theory presented by Robert Mazet at the Ecole Nationale Supérieure de l'Aéronautique, Paris. The author is head of structures and vibration research at the Office National d'Etudes et Recherches Aéronautiques of France (ONERA) and Professor at the Aeronautical College of Poitiers. Maurice Roy, Director, ONERA, has written the preface.

The level of the material presented is, by American standards, advanced senior year or first-year graduate school for engineering students. An auxiliary purpose served by the book is to acquaint working engineers in the mechanical, aeronautical, and related fields with the theory of linear vibrations. The presentation is based on the use of the notions of Lagrange in advanced mechanics and the ideas of operational calculus, the latter being developed neatly to the minimum extent necessary for the material that follows.

The book benefits from the author's experience with aeronautical problems at ONERA and reflects the emphasis placed upon mechanical vibration studies of aircraft by that organization. It is a valuable complement to existing works in the field, particularly in the following regard: the introduction and use of operational calculus, so applicable to the various aircraft stability and response problems and to servomechanisms; the particularly logical approach of the author in providing basic "test" theories for a structure under vibration study and, by their systematic application, for determining its characteristics (in short, in proposing the basic revelatory tests that the research engineer may perform); the presentation of a good variety of examples taken from several mechanical and electromechanical fields—in particular, for aircraft, the examples of a damped, flexibly mounted engine, wing vibration, landing gear vibration, flexure-torsion wing flutter, etc. (the author does not discuss in detail the origin or mathematical form of the theoretical aerodynamic forces of flutter); and an introduction to nonlinear vibrations.

The book consists essentially of theory oriented for use by a practicing engineer; it is in no sense a compendium of practical tricks or special industrial applications. It should be mentioned that the systems treated in all but the last chapter are those classical ones that are describable by linear differential equations.

A brief review of the contents of the book follows.

Chapter I, General Aspects of Vibrating Systems, presents the mathematical form taken by the elementary linear mechanical and electrical vibrating systems in one degree of freedom in the absence of damping. Methods are given for linearizing a given problem with the view of treating it by small vibration theory.

Chapter II, Conservative One-Degree-of-Freedom Vibrating Systems. Here, the theory for four basic investigatory vibration tests is given—that is, the study of the response (1) to release from static position of rest, (2) to step function force application, (3) to percussion, and (4) to harmonic force input. In connection with the discussion of these tests, operational calculus methods are introduced which are used thenceforth throughout a large part of the book.

Chapter III, Dissipative Vibrating Systems in One Degree of Freedom, applies the methods developed in Chapter II to the viscously damped elastic system. Herein are developed the essential basic notions for the common study of vibrating systems. Electric analogies for these systems are cited.

Chapter IV, Notion of Couplings; Conservative Systems with Two and More Degrees of Freedom, discusses vibration modes, normal forms, and elastic, mass, gyroscopic, and electromechanical coupling. There is a good number of examples, one of which is the T-beam simulating an aircraft wing in bending and torsion.

Chapter V, Chain Systems; Filters; Continuous Conservative Systems. This chapter discusses such problems as plate vibration and oscillations of continuous beams and bars in torsion and bending. Methods are given for their solution by both continuous and discrete-element analysis. A typical example here is the cantilever aircraft wing.

Chapter VI, Dissipative Systems with Several Degrees of Freedom, deals with elastic and viscous coupling of two systems and their resulting resonance characteristics; vibration damping by dissipative coupling; impedance matching in mechanical and electromechanical systems; aircraft wing vibration with consideration of internal viscous damping; and practical methods of determining the natural modes of an airplane.

Chapter VII, Vibration Systems Associated with a Reservoir of Energy, treats essentially of so-called self-excited systems: vibrational instability due to the tapping of an energy source. The classic examples cited are the simple servomechanism with return and the lifting-surface flutter of aircraft; the latter is dealt with in some detail. The Routh and Nyquist stability criteria are exposed.

Chapter VIII, Effect of Nonlinear Factors. This brief final chapter points out that all the mechanical systems treated are nonlinear and can be treated by linear means only when some clear notion of the degree of departure from linearity exists. The author suggests means of dealing with viscous and dry friction and discusses the case of structures departing from their elastic range. The important nonlinear characteristic wherein impedances, admittances, and transfer functions become dependent on the amplitude of the excitation is pointed out. The author discusses very briefly a generalized Van der Pol equation. A final example concerns the vibration of a low-damped system near resonance when excited by a rotary unbalance shaper.

A minor criticism: the book could profit by the addition of a detailed index.

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Book Notes

AERODYNAMICS

A Selection of Graphs for Use in Calculations of Compressible Airflow. Prepared on Behalf of the Aeronautical Research Council by the Compressible Flow Tables Panel, L. Rosenhead, Chairman. New York, Oxford University Press, 1954. 115 pp., diagrs., figs. $13.45.

This book and its companion volume, *Compressible Airflow: Tables* (Clarendon Press, 1952), have been prepared at the request of the British Aeronautical Research Council. The object of both books is to make available to engineers, physicists, and applied mathematicians a selection of tables and graphs likely to be of value in research and in calculations of the flow of air in which compressibility effects are important. It is hoped that they will be useful both as an aid to design and for the development of new theory.

This book contains graphs of some mathematical functions that occur in the theory of the steady flow of air in which the effect of compressibility is taken into account. The ratio of the specific heats of air, γ, has been taken to be 1.4, and the coefficient of viscosity of dry air at 23°C., μ, to be (183.00 $\pm$ 0.25) micropoises. In other units and at the standard sea-level temperature of 15°C., this coefficient is equivalent to (374.1 $\pm$ 0.5) $\times 10^{-9}$ slug/ft.sec.

The graphs have been grouped in sections labeled A, Isentropic Flow; B, Normal Shocks; C, Oblique Shocks; D, Conical Flow; and E, Reynolds Numbers. Each section contains its own introduction, which is reasonably self-contained and compact. The basic equations used for the graphs are given in full; together with the brief explanations they should enable any investigator in this field to make the fullest use of the graphs and to extend them if he has occasion to do so. For a more comprehensive account involving the derivation of the equations from first principles the reader is referred to *Modern Developments in Fluid Dynamics: High Speed Flow* (Clarendon Press). Cross references to the companion volume of tables have been reduced to a minimum, though, in general, it will be found most satisfactory to consult both the *Tables* and the *Graphs* before and during investigations.

Strömung durch Rohre; Umströmung von Körpern bei zweidimensionaler Strömung; Umströmung von Körpern bei räumlicher Strömung (Flow through Tubes; Two-Dimensional Flow around Bodies; Three-Dimensional Flow around Bodies). L. Schiller. Berlin, Springer-Verlag, 1955. 135 pp., diagrs., figs. In German.

This volume is a special reprint of pages 662–796 of First Part of the Second Volume of the Landolt-Bornstein *Numerical Values and Functions in the Fields of Physics, Chemistry, Astronomy, Geophysics, and Technology* (6th Edition). More than 100 topics are covered, and the compilation includes numerical data, curves, and equations. References to original literature sources are given in each case.

AIRPLANE DESIGN

Flight Handbook; The Theory and Practice of Aeronautics. Compiled by the Staff of *Flight*. Edited by Maurice A. Smith. 5th Ed. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1954. 282 pp., illus., diagrs., figs. $6.00.

Completely rewritten and greatly enlarged, this new edition deals with the atmosphere and its effect on flying, first principles of aerodynamics, aircraft structures, landing gear, controls, fixed-wing aircraft, gliders, sailplanes, rotorcraft, balloons, airships, piston engines, gas turbines, ramjets, pulse-jets, rockets, propellers, armament, instruments, and navigation.

MATERIALS

Electrons, Atoms, Metals and Alloys. William Hume-Rothery. Revised Ed. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1955. 387 pp., illus., diagrs., figs. $10.

This volume on the application of electron theory to the structure and properties of metals and alloys is intended for those to whom the ordinary mathematical treatment is unattractive. It is divided into four parts dealing with the structure of atoms, metals, alloys, and atomic nuclei and is presented in the form of a dialogue between an Older Metallurgist and a Young Scientist, bringing out the contrast between the old and the new viewpoints. Many difficulties are discussed, and the dialogue is framed to give the reader continual help in understanding the problems at issue. Although written primarily for the metallurgical reader, the book should prove valuable to many others as an elementary introduction to modern atomic theory, while for students it may serve as an easy introduction to the more formal treatment of the standard textbooks.

1954 Supplement to the Metal Cleaning Bibliographical Abstracts. Jay C. Harris. Philadelphia, American Society for Testing Materials, 1954. 40 pp. $1.50.

This Supplement brings up to date the 1953 edition, which was a combined publication of all references from 1842 to 1951. New references total 227.

MATHEMATICS

Transform Calculus; With an Introduction to Complex Variables. E. J. Scott. New York, Harper & Brothers, 1955. 330 pp., diagrs., figs. $7.50.

This is a text for courses centering around the Laplace transform for advanced mathematics majors, physicists, and engineers. The text begins with a chapter on the functions of a complex variable, containing as much theory as is necessary for an understanding of the Laplace transform. The theory of the Laplace transform is discussed from this point of view, and the residue theory and contour integration play an important part in its development. Matrix algebra is used systematically in the solution of systems of ordinary differential and difference equations, since its use enables one to write a complex system of equations as a single matric equation, thus facilitating its solution. The unit function and the unit impulse function are made to play an important role in the solution of physical problems because of the added power they give the Laplace transform method. The text is fully illustrated and amply provided with problems, and solved problems are used to illustrate the theory. Answers are given for many of the problems. The appendix material provides references for further reading and a number of tables.

REFERENCE WORKS

Who's Who in World Aviation, Vol. 1. Washington, American Aviation Publications, Inc., 1955. 345 pp. $10.

Approximately 2,400 persons are covered in this first edition. Included are officials and key persons in industry, Government, and research and in the principal aeronautical organizations, and individuals who have won recognition by reason of their contributions to the science, industry, commerce, literature, and development of aviation and its allied fields.

Aeronautical Research Council. Government Publications Sectional List No. 8. Revised to May, 1954. London; H.M. Stationery Office; New York, British Information Services, 1955. 159 pp.

A subject list of Reports & Memoranda, Current Papers, and the older series of E.S.C. publications. Title, date, and price (for those in print) are given in each case. There is also a numerical index.

List of Publications. College of Aeronautics, Cranfield, Bletchley, Bucks, England, January, 1955. 7 pp.

A numerical list of its *Reports* and of those *Notes* that are available for general distribution.

IAS Twenty-Fourth Annual Meeting

Hotel Sheraton-Astor, New York City, January 23-27, 1956

The Meetings Committee plans to schedule sessions on Aerodynamics, Aeroelasticity, Design, Electronics, Flight Propulsion, Instruments, Rotating Wing Aircraft, Safety in Flight, Structures, etc.

Members or organizations wishing to have papers considered for presentation at this meeting should submit outlines or short abstracts to the Meetings Committee, 2 East 64th St., New York 21, N.Y., no later than September 1, 1955.